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STRONG MOTION ARRAYS IN INDIA AND CHARACTERISTICS OF RECENT RECORDED EVENTS**

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ABSTRACT

For aseismic design of structures and systems it is required to postulate the time history or its derived form in the form of response spectra for the site. For this purpose a data-base of strong motion accelerograms appropriate to the site is needed. Himalayan region being most seismic in India, two strong motion arrays were planned and installed-One in Shillong Region of N.E. INDIA and the other in Kangra region of N.W. INDIA so that such a data base can be acquired in future. This paper describes the salient features of these two arrays. One event in Kangra array and four events in Shillong array have occurred since their installation. These records have been analysed and strong motion characteristics of these events have been discussed. These are the first records from the Himalayas which are of interest to the profession worldwide.

INTRODUCTION

In India, the evaluation of design earthquake parameters has been mainly based on data obtained in Western U.S.A. as recorded strong motion was almost non-existant in India with the first record having been obtained in Koyna dam region only in 1967 and first record in Himalayas in 1986. A number of dams have been instrumented since 1970 but no substantial records have been obtained. Since 1976, the Department of Science & Technology (DST), Government of India have been funding a Indian National Strong Motion Network program in the

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country through which about 80 three component analog strong motion accelerographs have been installed with a very wide spacing in the seismic zones V and IV along the Himalayas and its foot hills.

In 1978, an International workshop was held at Honolulu wherein it was recommended that dense strong motion arrays should be installed in select locations which have potential for occurrence of large earthquake (Ref. 1). The data obtained from such array would give impetus to research in Strong Motion seismology o evaluate the nature of the source mechanism, the influence of the wave propagation path and the effect of local topographic and soil conditions. That workshop also identified several sites in the world which included Shillong region in India as one of the six most potential sites.

Under an INDO-US collaboration Program, sponsored by DST, a fifty element analog accelerograph system(SMA-1 of M/s KINEMETRICS USA with time code generator) has baen installed at various locations in Kangra region of the State of Himachal Pradesh (Ref. 2). A second array of 45 analog system. sponsored by DST, has been installed in Shillong region of the States of Meghalaya and Assam (Ref. 3). One digital strong motion accelerograph also has been installed in each of these arrays-one at Dharmsala and the other at Shillong. Earthquake records from these digital instruments can be used for comparative studies with analog data results. A third array of 40 analog system is being planned in Himalayan region of the State of Uttar Pradesh.

The Kangra array registered an event on April 26, 1986 which triggered 9 stations since installation. This was the only significant activity so far of Magnitude 5.7. The Shillong array has registered 4 events : (i) September 10, 1986 of Magnitude 5.5 (IMD reported) by 12 stations (ii) May 18, 1987 of Magnitude 5.7 by 14 stations (iii) February 6, 1988 of Magnitude 5.8 by 18 stations and (iv) August 6, 1988 of Magnitude 7.2 by 33 stations. As expected, the Shillong region is more active and even in the short span of time, has produced valuable data.

This paper describes briefly the planning of the two arrays with respect to seismo-tectonic set-up in those regions. On an average the interstation spacing in Kangra array is 15 km, and 25 km in Shillong array.

The events recorded in the arrays have been analysed. Due to availability of absolute time in the records, the epicenter could be better located (Ref. 4). The uncertainties in the evaluation of epicenterand vast difference in their location as reported by different agencies cause a problem in arriving at attenuation relationship. It appears that epicentral information from strong motion data would be more useful in deriving attenuation relationship.

Statistical analysis were made of the response spectra values derived from the strong motion accelerograms. The shape of spectra is unique to this region, showing higher amplification in short period range and lower values at larger periods as compared to some standard shapes used in design. In the Shillong array where 77 three component records are now available, the acceleration and velocity patterns indicate strong influence of local geology.

DESCRIPTION OF THE ARRAYS

A. KANGRA ARRAY

Seismo Tectonic Set-up

The tectonic environment of Himalayas is shaped during early Tertiary times due to the mountain building processes. Among the various tectonic features, two are of prominence and can be traced all along the length of Himalayas. These features are essentially thrust sheets. The tectonic feature separating Tertiaries from Mesozoic is the Main Boundary Fault (MBF) and Mesozoic from central crystallines is the Main Central Thrust (MCT). Apart from these two regional tectonic features of prominence, there are local thrust sheets and tear faulting which demonstrate the neo-tectonic activity going on in the Himalayas.

The MBF is not a single continuous tectonic feature but occurs in the from of garlands with pronounced reentrants and is considered to be related to the extensions of the peninsular shield in the form of ridges against which the sediments were deposited and subsequently moulded. The formation of these reentrants perhaps have resulted in the early Tertiary times. The Tertiary belt forms the foothills of Himalayas having varied width and shows marked influence of peninsular basement faults. Holocene movements along these basement. lineaments, probably have given rise to tear faulting transverse to Himalayan trend.

The MBF and other thrust sheets are considered as the potential tectonic sources for earthquake activity in the region. Evidences of movements along Satlita thrust in the Beas river section have been reported and it has been inferred that continuous adjustments along with the downward extension of this thrust may have been responisible for the great 1905 Kangra earthquake. It has also been postulated that Siwalik hills represent the latest orogenic accretion of the Himalayas and therefore the outermost thrusts and faults like the Satlita and other faults may have an active seismic status.

Figure 1 shows the tectonic features and historically/instrumentally recorded earthquake of magnitude greater than 4. There are 69 earthquakse recorded during the period 1942-1985. Figure 2 shows the micro—earthquake activity recorded by closely spaced network of sensitive seismographs.

The tectonic features and seismic activity clearly indicate a northwest-southeast trend.

Array Pianning

Fifty analog instruments were made available under National Science Foundation sponsorhip for this INDO-US collaborative project. The site selection committee noted that three major rivers. namely, Ravi, Beas and Sutlej flow through this region and there are major multi-purpose hydroelectric projects located in the area. In view of the essentially thrust regime of the region, a two dimensional array was proposed and installed as shown in Figure 3. The array is trending northwest to southeast having a linear dimension of about 240 km. and is running parallel to the regional strike of the tectonic features. The width of the array in a directian transverse to the geological features varies from about 40 to 80 km. In total, an area of about 60 km $\times$240 km has been covered by this array. The interstation spacing varies between 7 to 21 km. Table 1 gives the locations.

The region has an undulating topography with hills and valleys. The elevations of the stations ranges between 470 m. to 2700 m and in one sense the array is somewhat three dimensional. Some of the sites are remote and generally the area is difficult to access during monsoon and winter. The instruments are located at plinth level of single-storeyed buildings which are owned by official agencies. This ensures safe upkeep and since the buildings are on rock outcrop there is negligent foundation interaction and the instruments could be deemed to be in free field.

The isoseismals of the only event recorded after installation have a very similar shape as that of the great Kangra earthquake with a reduced intensity. The Kangra region registersa 6^{+}event everyten years or so. The middle Himalayas in the form of Dhauladhar ridge risees very abruptly to heights of 4000 m and it is not possible to locate instruments on the northeast part beyond this ridge. This is not a drawback as the isoseismals indicate a pronounced elliptical shape with a large major axis parallel to this ridge.

B. SHILLONG ARRAY

Seismo-Tectonic set-up

This region has been identified by the Honolulu workshop as one of the six most potential sites of the Northeast India can be broadly classified into four geotectonic units, namely, Arunachal Himalayas, Lohit Himalayas, the Patkoi-Naga-Lushai-Arakan Yoma (Indo-Burma) hill ranges and Shillong plateau-Assam basin. Shillong massif and its northeasternly projected spur forms the basement on which the alluvium and unfolded Tertiary formations of Assam basin has been deposited. It forms a wedge shaped triangular crustal block bounded by Arunachal Himalayas towards northwest, Lohit Himalaya towards northeast, the Indo-Burma fold belt towards southeast, the Bengal-Burma basins on the south and Rajmahal-Garo-Sylhat gap towards the west. The contact of these geotectonic units with the Shillong plateau is marked by conspicuous thrust and tear faults. Two prominent tectonic features forming the boundary of Shillong plateau towards west and south are the Dhubri and Dauki tear faults respectively. the plateau is bounded towards northwest by Main Boundary Fault, towards northeast by Mishmi and Lohit thrusts, towards southeast by Naga thrust belts and on the south by Dauki tear fault which merges towards east with Haflong-Disang thrust Zone. This complex tectonic regime surrounding Shillong plateau reveal that the area has experienced great compressive stresses and resulting distortions due to northward and eastward slow movement of the Indian plate.

One of the largest magnitude earthquake in recent history occurred in Shillong area in 1897. During the period 1825 to 1985, 250 earthquakes of magnitude above 3.5 rocked the region. The WWSSN seismological observatory at Shillong has recorded a very large number of minor and micro-earthquakes in the region. These indicate that Shillong Plateau and its adjoining regions have high seismic status. The seismic activity along the Dauki-Haflong fault zone is comparatively lower and a seismic gap has been postulated along this fault zone.

Figure 4 shows the tectonic features and epicenters of past earthquake in the region. Earthquake activities for the period of 80 years are shown in Figure 5.

Array Planning

The seismotectonic setup indicates two types of source mechanisms which may have relation to the seismicity of the region of Shillong Plateau. These are strike-slip mechanism along Dhubri and Dauki tear faults and thrust/dip slip mechanism of Haflong-Naga-Lushai-Disang thrust zones. The tear faults were to be instrumented by comb shaped arrays and thrust faults by two dimensional arrays.

Fortyfive analog instruments of SMA-1 with TCG card of M/s Kinemetrics have been installed in the region as shown in Figure 6. A comb shaped array comprising about 20 instruments has been designed along Daukl fault between latitudes 250°N and 260°N with three projected legs. This array merges in the east with a two dimensional array of 25 instruments in the northeast-southwest trending Haflong thrust. Table 2 gives the location of the instruments. They are housed mostly in single storeyed buildings of Government or Semi-Government agencies. The interstation spacing in this array is rather large due to paucity of instruments and very difficult site conditions. The array has been extended slightly south of 250°N latitude as an earthquake of magnitude 5.7 occurred just before the installation of the array.

The interstation spacing is rather large particularly for the comb-shaped part of the array. More instruments are needed and *if it is not* forthcoming it would be a tough decision to deplete one part of the existing array to have a proper instrument spacing for the second part of the array as the opinion is divided regarding probability of occurrence of the large event either in Shillong plateau or in the so called seismic gap in Haflong region.

DATA RETRIEVAL

Transfer of Data from Digitizer to a Personal Computer

The analog record is available in the form of 70 mm wide photographic film. There are several traces on the film - three acceleration traces corresponding to three components (two horizontal in mutually perpendicular directions and one vertical); one time trace in the form of square pulse to define horizontal time base and some other reference traces. The nominal scale is 1 cm/sec for time and 2 cm/unit gravity for acceleration. Thus, if the threshold is set at 1%g, the record amplitude is 0.2 mm.

The original 70 mm film is laid on the back lighted top surface of the digitizer using an adhesive tape. The digitizer is CALCOMP 9000 with a resolution of 1000 points per inch. The cross-hair of the cursor is aligned manually, and at the push of a button the X-Y coordinate is available as an output. In this semiautomatic process, the digitization of the acceleration trace is done at unequal time intervals by selecting the characteristic points of the record all peaks and inflection points along with as many intermediate points as are needed for an accurate definition of shape.

The digitized data is acquired by the PC via the RS-232C port with the use of BITCOM communication software. The communication package requires data on the following items :-

(a) Communication Parameters-baud rate, data bits, stop bits, duplex, etc.

(b) Filters.

(c) Delays-inter-character delay, line delay.

These settings are quite easy to set with the help of the on-line help available with the program. Once successful parameters are determined for a given communication, they are saved in a configuration file for future use.

HIGHLIGHTS OF DIGITAL SIGNAL PROCESSING

The raw digitized data is to be processed in order to obtain corrected ground acceleration, velocity and displacement data. Subsequently, from the corrected ground acceleration data response of linear single degree of freedom viscously damped systems is evaluated which forms the most important information for earthquake engineering studies. Fourier spectra is also evaluated using FFT techniques. For more detail, reference can be made to Hudson (Ref.5) and Lee and Trifunac (Ref..6).

Obtaining Uncorrected Acceleration Data from Raw Digitized Data

From the raw digitized data, a base line is fitted to make the sum of the squares of the deviations from the zero line a minimum. Scaling parameters for the abscissa and ordinates are appropriately introduced and the output forms the uncorrected acceleration data. By linear interpolation, uncorrected acceleration data are sampled at equal time intervals of 0.005 second.

Sources of Error in Uncorrected Acceleration Data

To record ground accelerations, the relative response of a viscously damped single degree of freedom oscillator is obtained. The characteristics of the oscillator are chosen so that the recorded response represents the ground acceleration in the frequency range from zero to about 3/4 of the natural frequency of the oscillator, which is about 25 cps. The output is in analog form and it is digitized as described above.

The exact absolute acceleration of site on which the instrument is placed is subjected to two transformation stage of "uncorrected accelerogram". The first transformation occurs in the accelerograph while the second one is due to digitizing process. The characteristics of the transform functions both for the oscillator of the accelerograph and the digitizing process are logically equivalent to a low-pass filter. If the low frequency f_l and high frequecy f_h are know, the uncorrected data can be corrected to represent the ground acceleration accurately in the frequency range between f_l and f_h.

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The main sources of long period errors are:

(a) due to transverse play of the film in the drive mechanism
(b) due warping of the film and
(c) random errors generated during digitization.

The main sources of high frequency errors are:

(a) modification of response due to amplitude and phase characteristics of oscillatar
(b) due to imperfection of the transducer and
(c) inadequate resolution of digitizer.

The steps used in the correction of the data is shown in the block Diagrams 1-3.

EFFECT OF FREQUENCY SETTINGS OF DIGITAL FILTER

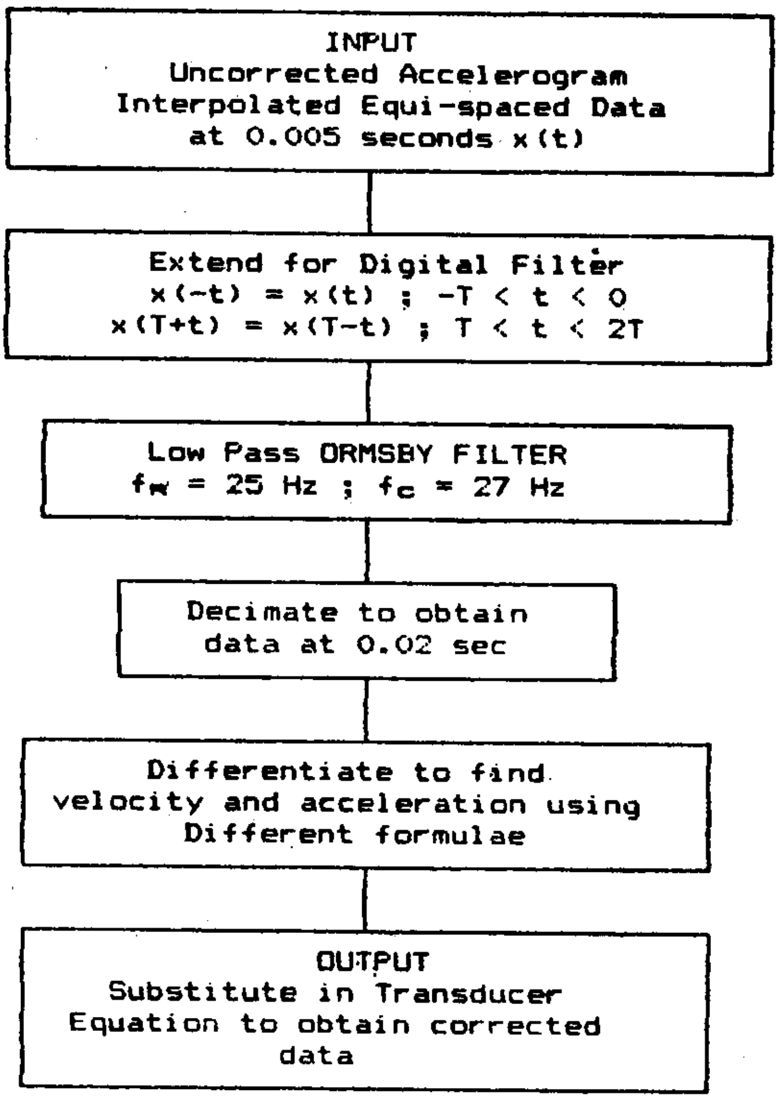
In the earthquake reports initially put out by CALTECH, the frequency settings of the ORSMBY filter were 0.05-0.07 Hz and 25.0-27.0 Hz. It is now known that the waveform of ground displacement as well as its magnitude is dependent on the method of digitization and filter settings. Comparative results for different values of low frequency settings for one component of the record during the event ot August 6, 1988 is given in Table 3.

Lee and Trifunac (Ref. 7) have now proposed a dynamic method of choosing filter settings. We had digitized several straight lines particularly to determine the low frequency settings. We decided that instead of dynamically evaluating filter settings, we would keep fixed values (by considering information only upto 5 seconds) so that if ground displacement values are used for attenuation studies, they belong to the same filter settings. The values adopted in our study are 0.17-0.20 Hz and 25.0-27.0 Hz.

DATA ANALYSIS

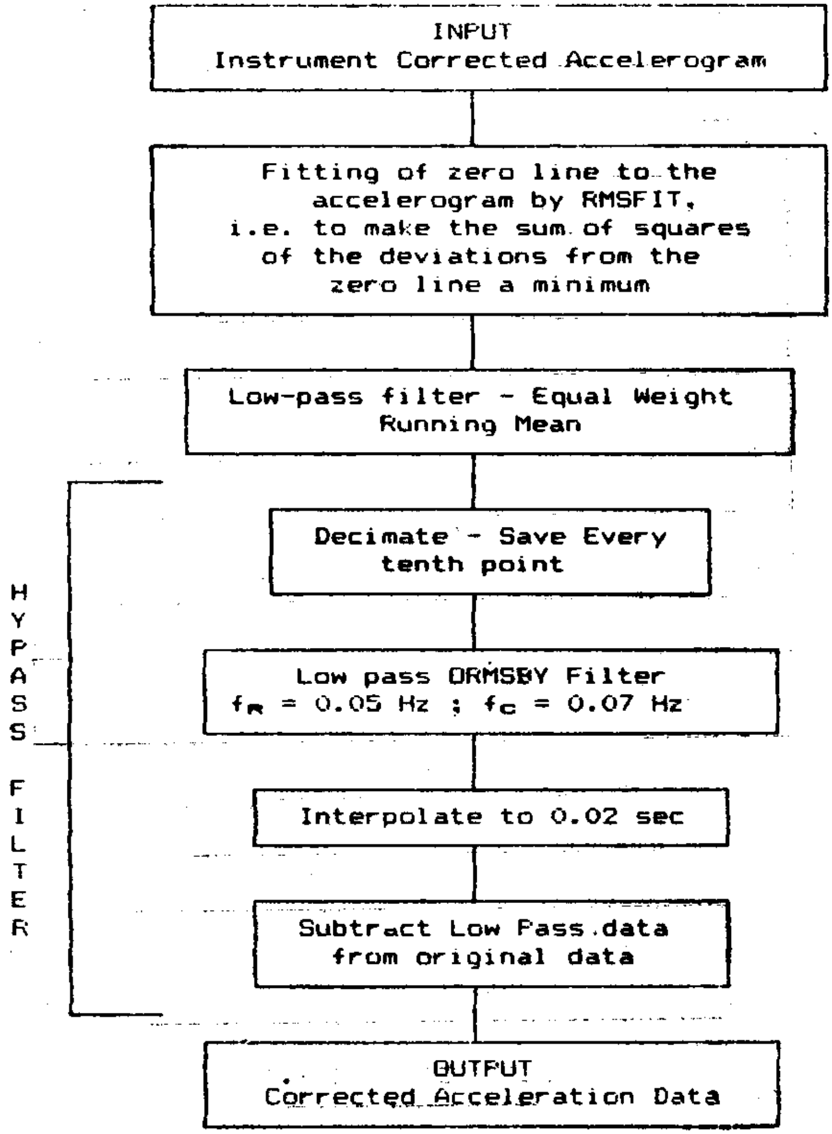
The raw uncorrected data acquired by PC from digitizer is transferred from PC to a mainframe computer through KERMIT communication software. All processing is done on the mainframe by special purpose

TRANSDUCER CORRECT



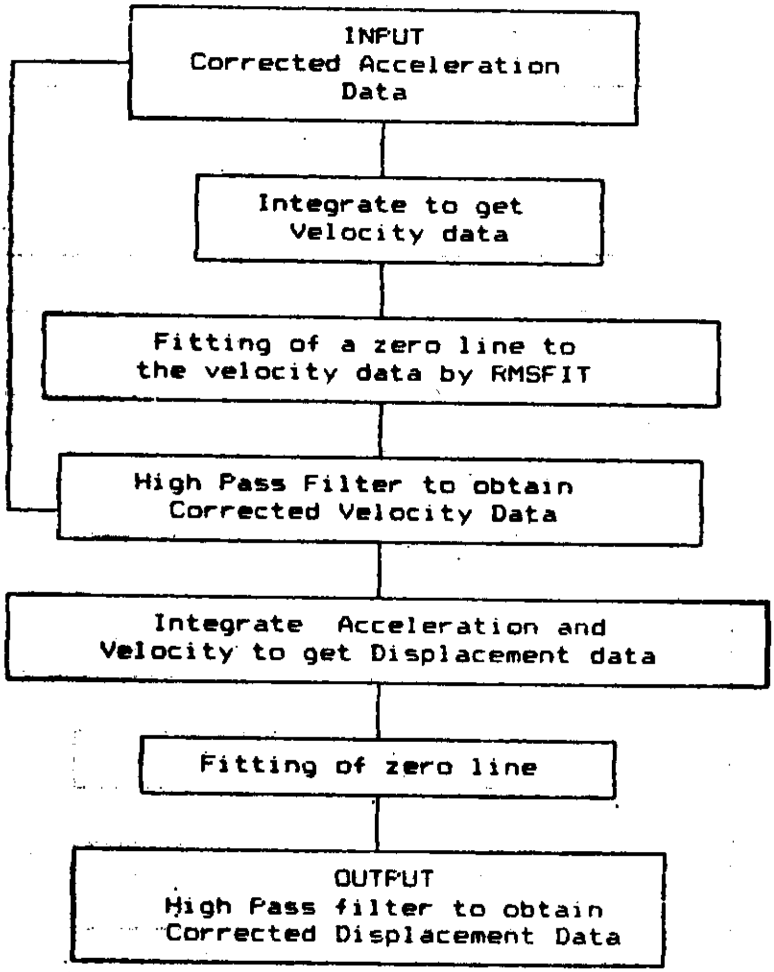
BLOCK DIAGRAM - 1

BASE-LINE CORRECTION TO OBTAIN CORRECTED ACCELERATION DATA



BLOCK DIAGRAM - 2

CORRECTED VELOCITY AND DISPLACEMENT DATA



BLOCK DIAGRAM - 3

computer programs and processed data transferred back to PC for plotting on a MP 3100 flatbed plotter connected to the PC.

DESCRIPTION OF THE EVENTS

A. APRIL 26, 1986 Earthquake in Himachal Pradesh

The Magnitude reported by United States Geological Survey (USGS) is 5.5 and by IMD is 5.7. Fig. 7 shows the location of postulated epicenters in which the maximun value of resultant peak acceleration of horizontal components at the various stations are also shown. E1 is the first estimate put out by India Meteorological Department (IMD); E2 that of USGS; E3 from Array records and E4 modified estimate by IMD taking array data in addition to that from seismograph stations. All the stations are on reasonably firm ground condition. From distribution of acceleration at the stations that recorded this earthquake it appears that E3 or E4 could be the likely epicenter. If attenuation relationship are worked out from epicenter. E1 or E2, it would be a poor fit of the recorded value.

Table 4 gives the peak value of acceleration, velocity and displacement at the various stations. The maximum duration of the record is 20 seconds and the maximum values of acceleration, velocity and displacement are 2432 mm/sec^2, 147.80 mm/sec, 24.79 mm in horizontal direction and 809 mm/sec^2, 28.04 mm/sec, 7.53 mm in vertical direction (Ref.8).

Fig. 8 shows the mean shape of normalized spectra for 5% damping for the 18 horizontal components and 9 vertical components. For comparison, the shape of spectra as recommended by BLUME-USNRC (Ref.9) as well as that given in Indian Standards IS : 1893 (Ref.10) are also shown. In the Fig., the notation M-H indicates mean of horizonal components, M-V that of vertical components, M-B that of Blume Spectra and ISC that of IS Code. It can be seen that in the short period range from 0.04 to 0.25 sec, the values are larger than USNRC and at long periods, the values are considerably lower. The vertical component is smaller than horizontal component beyond period of 0.9 sec. The IS Code values are larger than even USNRC beyond 0.4 sec period. The IS Code shape needs a revision in the long period rang.

B. SEPTEMBER 10, 1986 Earthquake In Meghalaya

USGS reported a Magnitude of 5.2 for this earthquake and IMD a value of 5.7. Location of postulated epicenters and maximum value of resultant peak acceleration of horizontal components at the various stations are shown in Fig. 9. IMD estimate of epicenter for this earthquake is shown as E 1 ; E2 that of USGS; E3 from Array records. Stations Nongkhlaw, Nongstoin, Pynursla and Khliehriat are on reasonably firm ground condition and rest of the eight stations are located either on soil or soft sedimentary rocks. From acceleration pattern it appears that E3 could be the likely epicenter.

The derived values of peak acceleration, velocity and displacement at the various stations given in Table 5. The maximum duration of the record is 29 seconds and the maximum values of acceleration, velocity and displacement are 1359 mm/sec^2, 58.73 mm/sec, 9.32 mm in horizontal direction and 607 mm/sec^2, 20.06 mm/sec, 6.83 mm in vertical direction (Ref. 11).

Fig. 10 depicts the mean shape of normalized spectra for 5% damping for the 24 horizontal components and 12 vertical components. The shape of spectra as recommended by BLUME are also shown. It can be seen that in the short period range from 0.04 to 0.24, the values are larger than USNRC and at long periods, the values are considerably lower. The vertical component is larger than horizontal component beyond period range of 0.5 sec.

C. MAY 18, 1987 Earthquake in N.E. INDIA

Magnitude of this earthquake of May 18, 1987 is 5.7 as reported by USGS. The maximum value of resultant peak acceleration of horizontal components at the various stations, which recorded this earthquake and location of postulated epicenter is shown in Fig. 11. IMD gave E1 as the epicenter estimated using data from seismological observatories; E2 that of USGS; E3 from Array records. Stations are located either on soil or soft sedimentary rocks. From acceleration recorded at various stations with trend of decrease in acceleration away from epicenter, E3 could be likely epicenter.

Table 6 gives the peak value of acceleration, velocity and displacement at the various stations. The maximum duration of the record is 42 seconds and the maximum values of acceleration, velocity and displacement are 843.3 mm/sec², 38.07 mm/sec, 11.54 mm in horizontal direction and 53.00 mm/sec², 19.24 mm/sec, 7.47 mm in vertical direction (Ref. 12).

Figure 12 shows the mean shape of normalized spectra for the 28 horizontal components and 14 vertical components. For comparison, the shape of spectra as recommended by BLUME are also shown. It can be seen that in the short period range from 0.04 to 0.30 sec, the values are larger than USNRC and at long periods, the values are lower. The vertical component shows almost same trend as horizontal component and beyond 0.8 sec. period range it is larger than horizontal.

D. FEBRUARY 6, 1988 Earthquake in N.E. INDIA

The Magnitude reported by USGS is 5.8. Fig. 13 shows the location of postulated epicenters in which the maximum value of resultant peak acceleration of horizontal components at the various stations are also shown. E1 in the first estimate put out by IMD; E2 that of USGS; E3 from Array records. Stations Nongkhlaw. Mawphlang, Pynursla and Khliehriat are on reasonably firm ground condition and rest of the fourteen stations are either on soil or soft sedimentary rocks. It appears that E3 could be the likely epicenter from the distribution of acceleration.

Table 7 gives the peak value of acceleration, velocity and displacement at the various stations. The maximum duration of the record is 45 seconds and the maximum values of acceleration, velocity and displacement are 1121 mm/sec², 52.63 mm/sec, 11.41 mm in horizontal direction and 1008 mm/sec², 35.10 mm/sec, 11.23 mm in vertical direction (Ref. 13).

Fig. 14 shows the mean shape of normalized spectra for the 36 horizontal components and 18 vertical components. For comparison, the shape of spectra as recommended by BLUME are also shown. It can be seen that in the short period range from 0.04 to 0.25 sec, the values are larger than USNRC and at long periods, the values are lower. The vertical component shows same trend as horizontal component, but beyond 0.45 sec period it is larger than horizontal component.

E. AUGUST 6, 1988 Earthquake in N.E. INDIA

This earthquake of August 6, 1988 was considerably strong and a vast area had been shaken. The Magnitude of this earthquake estimated by USGS is 7.2. Fig. 15 shows the location of postulated epicenters in which the maximum value of resultant peak acceleration of horizontal components at the various stations are also shown. Fig. 16 shows the resultant peak horizontal velocity from these records. IMD suggested the epicenter at E1; E2 that of USGS; E3 from Array records. Stations Nongstoin, Nongkhlaw, Mawkyrwat, Mawphlang, Mawsynram, Cherrapunji, Pynursla and Khliehriat are on reasonably firm ground condition and rest of the 26 stations are located either on soil or soft sedimentary rocks. The acceleration at various stations indicate a non-uniform distribution. It seems, that some of these high accelerations may be also due to local geological effect. Further, the ratio of acceleration to velocity at various stations as given in Fig. 17 exhibits random pattern. It needs adequate data supplementation from other local seismograph stations in India and Burma for a better location of epicenter. Moreover, having data only from one side, radial effect on epicenter estimation could not be achieved. It appears E3 may be a better estimate of the epicenter.

The estimated peak value of acceleration, velocity and disp lacement at the various station is given in Table 1. The maximum duration of the record is 120 seconds and the maximum values of accelertion, velocity and displacement are 3371 mm/sec2, 228.19 mm/sec 36.30 mm in aorizontal direction and 1765 mm/sec2, 90.26 mm/sec, 13.18 mm in vertical direction (Ref. 14).

Mean shaps of normalized mean spectra for the 66 horizontal components and 33 vertical components are depicted in Fig. 18, 19 and 20 Spectra have also been calculated considering such data with horizontal motion only above 0.05g and 0.10g and vertical motion above 0.025g and 0.05g These case are denoted as H:0.025, V:0.05 and H:0.05, V:0.10. The shape of spectra as recommended by BLUME are also shown. It can be seen that the values are larger than USNRC in 0.04 to 0.3 sec period range. The values for vertical component in case of Mean Spectra becomes larger than that of Blume beyond period 0.75 sec., but horizontal componenf first shows larger value than Blume in 0.6 to 1.25 sec range then comes smaller. But, *in* case of of Mean Spectra (H:0.05, V:0.025), the horizontal component shows almost same trend as Blume except in 0.7 to 1.2 sec period range, where the horizontal component has higher value. Blume values are considerably larger in case of Mean Spectra (H:0.10, V:0.05) in longer period range, and vertical and horizontal compoent show same values beyond 1.1 sec period range. It appears that smaller intensity accelerograms influence the shape in the long period range.

DISCUSSIONS AND CONCLUSIONS

The Shillong array has already recorded four strong events within three years of its installation. For a comparable event, the felt area is larger in case of Shillong as compared to Kangra region as can be seen form the events of the April 26, 1986 in N. W. India and May 18 1987, Fed. 6, 1988 in N. E. India. The duration of record is also larger in N. E. India. The attenuation appears to be more rapid in the Kangra region. Absolute time recording of the strong motion array helps in better estimation of epicenter when this data is used in conjunction with seismograph data. The epicenter is also better located if the event is recorded within the array whereas with events located outside the array radial effect on hypocenter calculation could not be obtained. The location is influened to great extent by uniazimuthal properties leading to undesirably high residuals to body waves.

The acceleration pattern indicates that in some local pockets there is a larger magnification, probably due to local soil effect. This is particularly seen at Saitsama station which recorded all the four events of N. E. India.

The velocity pattern also shows the same trend of decreasing value away from epicenter but the ratio of maximum peak resultant acceleration to velocity shows a random pattern. This needs further investigation.

The range of acceleration in the Sept. 10, 1986; May 18, 1987; Feb. 6 1988; August 6, 1988 acceleroagrams recorded during the four events in N. E. India is 83 to 3371 mm/sec2 in horizontal direction and 94 to 1765 mm/sec2 in vertical direction. Fig. 21 shows the mean shape of spectra normalized to peak ground acceleration of unit gravity for these four events. In order to find out whether small intensity motions affect the shape of spectra, records below 0.05g in horizontal direction and 0.025g in vertical direction were not considered in obtainig another shape of spectra. This case is denoted as (H=0.05, V=0.025). Fig. 22 shows the mean shape of spectra for this case. In case of Mean Spectra the horizontal component shows higher values than Blume in period range of 0.04 to 0.3 sec and then it has considerbly lower trend, whereas the vertical component has higher value in 0.04 to 0.2 sec period range but it shows higher trend than horizontal component beyond 0.7 sec period and becomes almost equal to that of Blume. The same trend is also given by the Mean Spedtra (H:0.05, V:0.025), but in this case the vertical component has higher value than horizontal component beyond I sec period but with lower values than Blume. It can be concluded that there is more clarity in shape of speetra when smaller intensity motions are not taken into account.

The shape of spectra clearly points out that the standard shape of spectra like USNRC underestimate in the shorf period range (0.04 sec to 0.25 sec) and overestimates beyond 0.3 sec. The long period structures like earth and rockfill dams and long bridges would get a relief in design, if the shape of spectra as obtained from these actual events are used rather than on basing the design on shapes mostly derived from Californian data.

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TABLE - 1

LIST OF STATIONS OF KANGRA ARRAY

S.No.	Station Name	Latitude		Longitude		Elevation (in meters)
		Deg.	Min.	Deg.	Min.	
1. (31)	Aghar	31	36	76	34	880
2. (41)	Bagsiad	31	33	77	07	1850
3. (48)	Bagi	31	14	77	33	2870
4. (37)	Bajaura	31	50	77	09	1120
5. (40)	Bali	31	41	77	16	1120
6. (20)	Bandlakhas	32	07	76	32	1800
7. (18)	Baroh	31	59	76	18	720
8. (1)	Bhajradu	32	50	76	09	1720
9. (21)	Bhawarna	32	02	76	29	500
10.(23)	Bir	32	02	76	43	1560
11.(4)	Chamba	32	33	76	07	1000
12.(45)	Choridhar	31	21	77	18	1580
13.(5)	Chuwarikhas	32	25	76	01	1600
14.(16)	Dadasiba	31	55	76	05	470
15.(44)	Dalash	31	23	77	25	1870
16.(3)	Dalhousie	32	32	75	58	1900
17.(29)	Dharmpur	31	48	76	45	760
18.(14)	Dharmsala	32	12	76	19	1400

TABLE - 1

LIST OF STATIONS OF KANGRA ARRAY

S. No.	Station Name	Latitude Deg.	Latitude Min.	Longitude Deg.	Longitude Min.	Elevation (in metera)
19.(33)	Drang	31	48	76	56	980
20.(35)	Ghumarwin	31	26	76	42	740
21.(27)	Hamirpur	31	41	76	31	760
22.(10)	Jawali	32	08	76	00	550
23.(28)	Jhatingri	31	56	76	53	1960
24.(42)	Jhungi	31	25	77	05	1830
25.(15)	Kangra	32	05	76	15	950
26.(9)	Kotla	32	14	76	03	800
27.(32)	Kulu	31	57	77	06	1260
28.(47)	Kunihar	31	04	76	56	960
29.(24)	Ladbharol	31	56	76	42	740
30.(25)	Lambagaon	31	53	76	33	560
31.(22)	Nadaun	31	46	76	20	470
32.(17)	Nagrota Bagwan	32	06	76	22	800
33.(13)	Nagrota Suryan	32	03	76	05	500
34.(43)	Namhol	31	15	76	52	1170
35.(6)	Nurpur	32	18	75	53	600
36.(38)	Pandoh	31	40	77	03	880

TABLE - 1

LIST OF STATIONS OF KANGRA ARRAY

S.NO.	Station Name	Latitude Deg.	Min.	Latitude Deg.	Min	Elevation (in meters)
37.(26)	Patlander	31	46	76	32	800
38.(19)	Pragpur	31	49	76	12	560
39.(7)	Rakh	32	28	76	14	2200
40.(34)	Rewalsar	31	37	76	50	1200
41.(11)	Rirkmar	32	18	76	11	1200
42.(49)	Sandhu	31	09	77	22	2410
43.(30)	Sarkaghat	31	42	76	44	900
44.(12)	Shahpur	32	12	76	11	700
45.(50)	Shimla	31	06	77	13	2200
46.(8)	Sihunta	32	18	76	05	1000
47.(39)	Sundernagar	31	33	76	54	840
48.(2)	Sundla	32	40	76	02	800
49.(46)	Sunni	31	14	77	20	680
50.(36)	Surani	31	53	76	20	900

Note : Cooridinates and elevations are somewhat approximate.
Numbers within bracket correspond to Nos. of Fig. 3.

TABLE - 2

LIST OF STATIONS OF SHILLONGARRAY

S.No.	Station Name	Latitude Deg.	Latitude Min.	Longitude Deg.	Longitude Min.	Elevation (in meters)
1.	(29) Baigao	25	24	92	51	650
2.	(23) Baitha Langso	25	58	92	36	70
3.	(37) Bamungao	25	53	93	00	100
4.	(41) Berlongfer	25	46	93	15	160
5.	(45) Bokajan	26	00	93	46	120
6.	(1) Boko	25	58	91	14	50
7.	(8) Cherrapunji	25	16	91	44	1140
8.	(15) Dauki	25	11	92	01	40
9.	(44) Diphu	25	55	93	26	160
10.	(31) Doloo	24	55	92	47	100
11.	(33) Gunjung	25	18	93	00	540
12.	(34) Haflong	25	10	93	01	540
13.	(42) Hajadisa	25	22	93	18	280
14.	(30) Harengajao	25	06	92	51	160
15.	(38) Hatikhali	25	39	93	06	140
16.	(27) Hojai	25	59	92	51	70
17.	(14) Jarain	25	19	92	07	360
18.	(21) Jellalpur	25	00	92	27	500

TABLE-2

LIST OF STATIONS OF SHILLONG ARRAY

S. No.	Station Name	Latitude Deg.	Latitude Min.	Longitude Deg.	Longitude Min.	Elevation (in meters)
19. (36)	Jhirighat	24	48	93	06	40
20. (25)	Kalain	24	58	92	34	20
21. (26)	Katakhal	24	49	92	38	20
22. (22)	Karimganj	24	51	92	21	20
23. (19)	Khliehriat	25	21	92	22	1180
24. (35)	Koomber	24	57	93	00	60
25. (43)	Laisong	25	12	93	18	800
26. (39)	Langting	25	29	93	07	160
27. (18)	Laskein	25	30	92	24	1200
28 (3)	Loharghat	25	58	91	28	6o
29. (40)	Maibang	25	18	93	08	150
30. (4)	Mawkyrwat	25	22	91	28	1000
31. (7)	Mawphlana	25	27	91	46	1700
32. (6)	Mawsynram	25	17	91	35	1360
33. (5)	Nongkhlaw	25	41	91	38	900
34. (9)	Nongpoh	25	54	91	52	560
35. (2)	Nongstoin	25	30	91	16	1400
36. (28)	Panimur	25	39	92	48	150

TABLE- 2
LIST OF STATIONS OF SHILLONG ARRAY

S. No.	Station Name	Latitude Deg.	Latitude Min.	Longitude Deg.	Longitude Min.	Elevation (in meters)
37. (12)	Pynursla	25	18	91	54	1300
38. (17)	Saitsama	25	43	92	23	900
39. (11)	Shillong	25	33	91	54	1540
40. (32)	Silchar	24	49	92	48	20
41. (16)	Ulukunchi	25	58	92	18	500
42. (20)	Umkiang	25	08	92	20	800
43. (13)	Ummulong	25	30	92	09	1300
44. (94)	Umrongso	25	30	92	37	720
45. (10)	Umsning	25	44	91	53	800

Note: Coordinates and elevations are somewhat approximate.
: Numbers within bracket correspond to Nos. of Fig. 6

TABLE 3

COMPARATIVE RESULTS FOR DIFFERENT VALUES OF LOW FREQUENCY SETTING

Response	LOW FREQUENCY SETTING IN Hz			
	0.05.0.070	0.91-3. 100	0.10-0. 125	0.17–0.20
Acceleration (in cm/s*s)	335.933	335.911	336.028	337.073
Velocity (in mm/s)	215.028	209.542	208.626	228.189
Displacement (in mm)	58.554	53.899	45.308	36.303

TABLE 4

SUMMARY OF STRONG MOTION DATA
DHARMSALA EARTHQUAKE APRIL 26, 1986 HIMACHAL PRADESH, INDIA

S.	LOCATION	COMPONENT	DERIVED MAXIMUM PEAK GROUND ACCELE-RATION IN CM/SEC/SEC	DERIVED MAXIMUM PEAK GROUND VELOCITY (MM/SEC)	DERIVED MAXIMUM PEAK GROUND DISP-LACEMENT (MM)
1	2	3	4	5	6
1.	Bandlakhas	L-S 27 E	142.49	83.13	20.08
		V-VERT	22.07	15.63	6.33
		T-N 63 E	122.36	50.75	5.85
2.	Baroh	L-N 25 W	57.56	36.80	6.55
		V-VERT	22.31	15.07	3.64
		T-N 65 E	56.17	27.62	4.58
3.	Bhawarana	L-N 82 E	36.49	11.70	2.73
		V-VERT	35.36	9.34	21.13
		T-N 08 W	34.72	19.21	4.20

1	2	3	4	5	6
4.	Dharmsala	L-N 76 W	172.21	72 97	7.76
		V-VERT	80.94	27.39	4.19
		T-N 14 E	182.89	94.90	24.79
5.	Jawali	L-S 86 W	14 87	19.20	4.90
		V-VERT	10.81	14.39	7.53
		T-N 04 W	16.55	15.18	9.56
6.	Kangra	L-N 43 W	144.97	50.57	5.23
		V-VERT	70.77	31.93	5.37
		T-N 47 E	109.43	95.75	9.62
7.	Nagrotabagwan	L-S 85 W	145.53	94.17	13.09
		V-VERT	49.73	18.19	6.51
		T-N 05 W	78.59	25.40	6.14
8.	Shahpur	L-N 75 W	200.17	59.21	7.26
		V-VERT	64.31	28.04	5.25
		T-N 15 W	243.20	147.80	10.85
9.	Sihunta	L-N 25 W	50.41	26.72	4.71
		V-VERT	38.25	27.73	4.74
		T-N 65 E	35.32	33.88	3.67

TABLE 5

SUMMARY OF STRONG MOTION DATA
NE-INDIA EARTHQUAKE SEPT. 10, 1986

S.	LOCATION	COMPONENT	DERIVED MAXIMUM PEAK GROUND ACCELE-RATION IN CM/SEC/SEC	DERIVED MAXIMUM PEAK GROUND VELOCITY (MM/SEC)	DERIVED MAXIMUM PEAK GROUND DISP-LACEMENT (MM)
1	2	3	4	5	6
1.	Baithalangso	L-S 02 W	44.51	20.58	3.55
		V-VERT	24.58	10.91	4,74
		T-N 88 W	41.25	12.07	2.73
2.	Dauki	L-S 72 E	87.61	32.40	3.00
		V-VERT	31.20	14.14	5.92
		T-S 08 W	88.65	37.33	2.56
3.	Khliehriat	L-S 45 E	30.30	11.30	2.00
		V-VERT	1.45	7.71	1.95
		T-S 45 W	45.01	18.41	3.86

1	2	3	4	5	6
4.	Nongkhlaw	L-N 80 E	53.87	33.09	9.32
		V-VERT	33.55	14.11	6.83
		T-S 10 E	90.96	48.08	5.47
5.	Nongpah	L-N 40 E	52.87	21.13	4.26
		V-VERT	32.86	11.25	2.64
		T-S 50 E	54.53	11.32	4.59
6.	Nongstoin	L-N 65 E	19.01	10.04	4.90
		V-VERT	8.07	5.95	1.99
		T-S 25 E	13.59	6.48	1.66
7,	Panimur	L-N 65 E	38.35	9.37	2.02
		V-VERT	22.80	5.61	1.40
		T-S 25 E	47.71	21.15	2.65
8.	Pynursla	L-N 59 E	90.95	26.75	3.24
		V-VERT	29.68	9.28	3.80
		T-S 31 E	74.22	20.37	4.55
9.	Saitsama	L-N 85 E	110.87	36.69	4.90
		V-VERT	60.72	20.06	3.22
		T-S 05 E	135.86	58.73	4.92
10.	Ummulong	L-N 87 E	111.42	26.53	2.38
		V-VERT	47.91	14'25	3.21
		T-S 03 E	62.27	12.10	1.56

1	2	3	4	5	6
11.	Umrongso	L-S 27 W	26.73	9.68	1.30
		V-VERT	13.86	7.81	2.26
		T-N 63 W	31.36	11.84	4.41
12.	Umsning	L-N 45 E	99.49	28.72	3.42
		V-VERT	47.82	10.88	3.75
		T-S 45 E	74.89	25.67	3.93

TABLE - 6

SUMMARY OF STRONG MOTION DATA NE-INDIA EARTHQUAKE MAY 18, 1987

S. NO.	LOCATION	COMPONENT	DERIVED MAXIMUM PEAK GROUND ACCLE-RATION IN CM/SEC/SEC	DERIVED MAXIMUM PEAK GROUND VELOCITY (MM/SEC)	DERIVED MAXIMUM PEAK GROUND DISP-LACEMENT (MM)
1	2	3	4	5	6
1.	Baithalangso	L-S 02 W	33.59	15.53	4.15
		V-VERT	19.12	12.85	3.80
		T-N 88 W	26.26	21.56	8.11
2.	Bamungao	L-N 19 W	19.42	12.22	4.24
		V-VERT	18.60	13.62	3.32
		T-S 71 W	19.37	22,00	6.78
3.	Berlongfer	L-S 76 W	70.56	35.95	5.51
		V-VERT	45.19	19.24	7.47
		T-N 14 W	88.46	36.20	8.95

TABLE - 6

1	2	3	4	5	6
4.	Bokajah	L-N 34 E	29.33	25.69	9.34
		V-VERT	19.43	13.20	5.25
		T-S 56 E	64.40	34.28	10.31
5.	Diphu	L-N 90 E	84.33	27.69	5.80
		V-VERT	53.00	15.31	6.65
		T-S 00 W	71.93	23.92	11.54
6.	Gunjung	L-N 15 E	41.39	23.04	5.55
		V-VERT	18.26	10.83	3.38
		T-S 75 E	48.40	28.56	5.51
7.	Haflong	L-N 10 W	54.42	36.93	8.35
		V-VERT	14.79	12.15	3.06
		T-S 80 W	34.87	20.61	5.38
8.	Hajadisa	L-S 20 W	76.95	38.07	7.50
		V-VERT	27.73	15.34	3.49
		T-N 70 W	83.86	28.07	5.00
9.	Hatikhali	L-N 40 E	30.49	14.55	5.55
		V-VERT	26.34	18.58	3.64
		T-S 50 E	37.04	17.71	3.48

TABLE - 6

1	2	3	4	5	6
10.	Laisog	L-S 45 E	41.49	32.35	7.84
		V-VERT	18.15	13.54	6.20
		T-S 45 W	60.07	23.69	9.42
11.	Nongpoh	L-N 40 E	17.08	13.12	4.88
		V-VERT	13.75	9.55	3.13
		T-S 50 E	16.90	12.58	5.93
12.	Panimur	L-N 65 E	39.14	18.00	4.10
		V-VERT	17.25	16.79	5.78
		T-S 25 E	46.43	18.11	2.99
13.	Saitsama	L-N 85 E	36.40	13.92	3.36
		V-VERT	18.53	9.29	4.00
		T-S 05 E	48 53	22.84	8.91
14.	Umrongso	L-S 27 W	20.01	13.79	2.76
		V-VERT	15.95	9.13	2.91
		T-N 63 W	25.02	14.50	5.69

TABLE 7

SUMMARY OF STRONG MOTION DATA
NE-INDIA EARTHQUAKE FEB. 6, 1988

S.	LOCATION	COMPONENT	DERIVED MAXIMUM PEAK GROUND ACCELE-RATION IN CM/SEC/SEC	DERIVED MAXIMUM PEAK GROUND VELOCITY (MM/SEC)	DERIVED MAXIMUM PEAK GROUND DISP-LACEMENT (MM)
1	2	3	4	5	6
1.	Baigao	L-S 28 W	21.43	14.14	3.90
		V-VERT	9.61	11.27	3.26
		T-N 62 W	23.94	20.64	6.90
2.	Baithalangso	L-S 02 W	29.59	13.65	3.81
		V-VERT	13 70	7.44	1.76
		T-N 88 W	21-78	12.26	3.33
3.	Bamungao	L-N 19 W	16.04	5.08	1.30
		V-VERT	9.84	6.23	2.33
		T-S 17 W	13.05	10.35	2.30

TABLE - 7

1	2	3	4	5	6
4.	Dauki	L-S 72 E	25.99	18.01	2.50
		V-VERT	10.20	8.57	3.41
		T-S 08 W	37.93	18.37	4.41
5.	Gunjung	L-N 15 E	35.70	29.05	6.26
		V-VERT	19.14	12.87	3.30
		T-S 75 E	36.25	24.44	3.87
6.	Haflong	L-N 10 W	33.97	19.42	3.13
		V-VERT	7.88	7.22	1.99
		T-S 80 W	26.82	14.02	3.34
7.	Hatikhali	L-N 40 E	23.18	8.78	3.18
		V-VERT	20.95	7.29	1.98
		T-S 50 E	24.89	9.87	3.84
8.	Katakhal	L-S 89 E	9.20	10.64	3.04
		V-VERT	9.65	9.88	4.09
		T-S 01 W	8.34	7.75	1.60
9.	Khliehriat	L-S 45 E	78.19	47.46	8.45
		V-VERT	28.93	15.91	2.94
		T-S 45 W	64.86	27.87	3.44

TABLE - 7

1	2	3	4	5	6
10.	Mawphlang	L-S 35 W	79.61	43.85	7.97
		V-VERT	35.27	12.33	4.86
		T-N 55 W	57.68	24.89	10.14
11.	Nongkhlaw	L-N 80 E	105.44	42.94	9.50
		V-VERT	100.76	35.10	11.23
		T-S 10 E	112.09	52.63	11.41
12.	Nongpoh	L-N 40 E	26.90	15.89	4.64
		V-VERT	37.45	10.64	4.02
		T-S 50 E	84.62	26.45	3.75
13.	Pynursla	L-N 59 E	48.75	21.24	4.99
		V-VERT	15.00	9.43	3.63
		T-S 31 E	30.42	11.95	4.93
14.	Saitsama	L-N 85 E	64.58	22.38	4.50
		V-VERT	31.65	9.90	2.37
		T-S 05 E	57.06	32.43	4.37
15.	Shillong	L-N 40 E	46.72	16.06	5.16
		V-VERT	13.41	14.42	5.19
		T-S 50 E	35.13	15.39	7.89

TABLE-7

1	2	3	4	5	6
16.	Ummulong	L-N 87 E	55.30	22.48	5.69
		V-VERT	23.74	10.89	4.37
		T-S 03 E	53.73	21.42	6.35
17.	Umrongso	L-S 27 W	45.44	31.43	3.06
		V-VERT	21.26	12.26	2.38
		T-N 63 W	36 11	26.58	6.67
18.	Umsning	L-N 45 E	39.01	16.62	3.14
		V-VERT	17.76	11.95	3.55
		T-S 45 E	59.74	36.73	5.03

TABLE - 8

SUMMARY OF STRONG MOTION DATA
NE-INDIA EARTHQUAKE AUG. 6, 1988

S. NO.	LOCATION	COMPONENT	DERIVED MAXIMUM PEAK GROUND ACCLE-RATION IN CM/SEC/SEC	DERIVED MAXIMUM PEAK GROUND VELOCITY (MM/SEC)	DERIVED MAXIMUM PEAK GROUND DISP-LACEMENT (MM)
1	2	3	4	5	6
1.	Baigao	L-S 28 W	216.82	65.68	10.19
		V-VERT	51.90	20.11	5.85
		T-N 62 W	141.41	63.70	9.80
2.	Baithalangso	L-S 02 W	150.99	75.52	12.36
		V-VERT	80.40	36.12	6.98
		T-N 88 W	162.06	117.05	15.45
3.	Bamungao	L-N 19 W	91.50	64.03	8.96
		V-VERT	64.29	25.06	4.23
		T-S 71 W	68.59	49.80	10.23

TABLE - 8

1	2	3	4	5	6
4.	Berlongfer	L-S 76 W	295.11	217.24	33.40
		V-VERT	170.58	90.26	13.18
		T-N 14 W	337.07	228.19	36.30
5.	Bokajan	L-N 34 E	147.80	86.75	19.91
		V-VERT	145.00	32.49	9.14
		T-N 56 E	219.78	121.36	20.41
6.	Cherrapunji	L-S 55 E	51.06	21.47	3.57
		V-VERT	23.04	20.45	3.81
		T-S 35 W	53.65	26.78	6.22
7.	Dauki	L-S 72 E	106.60	46.87	7.56
		V-VERT	29.88	20.74	6.52
		T-S 08 W	71.70	44.53	5.78
8.	Diphu	L-N 90 E	277.25	181.48	23.25
		V-VERT	176.47	56.12	9.00
		T-S 00 E	331.37	205.55	22.74
9.	Doloo	L-S 41 E	63.05	58.89	14.40
		V-VERT	37.94	33.83	7.63
		T-S 49 W	60.99	53.49	12.61

TABLE - 8

1	2	3	4	5	6
10.	Gunjung	L-N 15 E	91.88	44.19	8.74
		V-VERT	60.98	25.56	6.74
		T-S 75 E	130.21	52.05	8.58
11.	Hajadisa	L-S 20 W	90.17	42.73	9.72
		V-VERT	45.27	22.28	5.98
		T-N 70 W	96.27	46.43	8.77
12.	Harengajao	L-S 60 E	63.89	40.99	7.57
		V-VERT	31.47	22.15	6 31
		T-S 30 W	76.68	44.39	8.92
13.	Hojai	L-S 82 W	105 68	51.88	14.06
		V-VERT	59.71	25.25	7.83
		T-N 08 W	131.05	65.61	11.61
14.	Jellalpur	L-N 88 W	28.91	30.40	4.81
		V-VERT	15.33	17.07	4.01
		T-S 02 W	22.66	20.46	5.18
15.	[illegible]ghat	L-N 47 W	95.71	88.30	11.15
		V-VERT	30.26	30.38	8.21
		T-S 43 W	87.47	70.35	10.05

TABLE - 8

1	2	3	4	5	6
16. Kalain		L-S 64 E	55.80	77.76	15.87
		V-VERT	28.12	43.21	10.89
		T-S 26 W	50.25	51.09	15.71
17. Katakhal		L-S 89 E	66.55	110.74	23.34
		V-VERT	17.62	33.72	10.11
		T-S 01 W	58.28	93.56	25.26
18. Khliehriat		L-S 45 E	68.78	29.21	4.55
		V-VERT	33.83	16.11	3.44
		T-S 45 W	70.10	31.74	5.42
19. Koomber		L-S 72 E	48.24	39.04	9.86
		V-VERT	26.30	23.23	5.57
		T-S 18 W	36.02	34.88	7.14
20. Loharghat		L-S54 E	56.78	36.58	8.58
		V-VERT	21.78	20.42	5,06
		T-S 36 E	53.42	48.61	9.91
21. Mawkyrwat		L-N 20 E	45.12	25.18	3.10
		V-VERT	31.57	17.51	4.69
		T-S 70 E	45.33	21.98	4.80

TABLE - 8

1	2	3	4	5	6
22.	Mawphlang	L-S 35 W	113.14	39.17	6.78
		V-VERT	35.47	12.52	3.85
		T-N 55 W	104.75	38.99	5.34
23.	Mawsynram	L-S 58 W	83.63	33.67	8.29
		V-VERT	35.17	21.45	5.89
		T-N 32 W	63.30	28.61	5.47
24.	Nongkhlaw	L-N 80 E	135.35	64.50	6.02
		V-VERT	81.62	34.17	9.46
		T-S 10 E	143.47	55.66	11.07
25.	Nongstoin	L-N 65 E	53.23	24.09	9.54
		V-VERT	40.84	14.80	6.14
		T-S 25 E	50.67	31.04	11.16
26.	Panimur	L-N 65 E	165.44	55.19	5.29
		V-VERT	71.62	20.85	6.14
		T-S 25 E	122.41	44.38	6.06
27.	Pynursla	L.N 59 E	48.41	42.13	5.92
		V-VERT	35.31	31.55	6.35
		T-S 31 E	50.37	32.24	7.22

TABLE - 8

1	2	3	4	5	6
28.	Saitsama	L-N 85 E	207.04	87.31	7.83
		V-VERT	96.73	33.77	4.82
		T-S 05 E	228.28	103.63	13.83
29.	Shillong	L-N 40 E	73.50	20.44	3.24
		V-VERT	35.12	9.75	3.31
		T-S 50 E	56.16	17.55	5.86
30.	Silchar	L-N 60 E	63.18	71.52	21.10
		V-VERT	24.76	29.98	8.62
		T-S 30 E	89.38	9876	21.13
31.	Umulong	L-N 87 E	98.14	30.76	7.86
		V-VERT	60.80	27.33	11.28
		T-S 03 E	149.76	43.95	12.80
32.	Umrongso	L-S 27 W	76.91	51.66	6.64
		V-VERT	43.67	17.48	4.46
		T-N 63 W	79.04	39.98	7.79
33.	Umsning	L-N 45 E	133.27	41.46	7.88
		V-VERT	69.78	38.31	12.50
		T-S 45 E	150.16	51.94	10.12

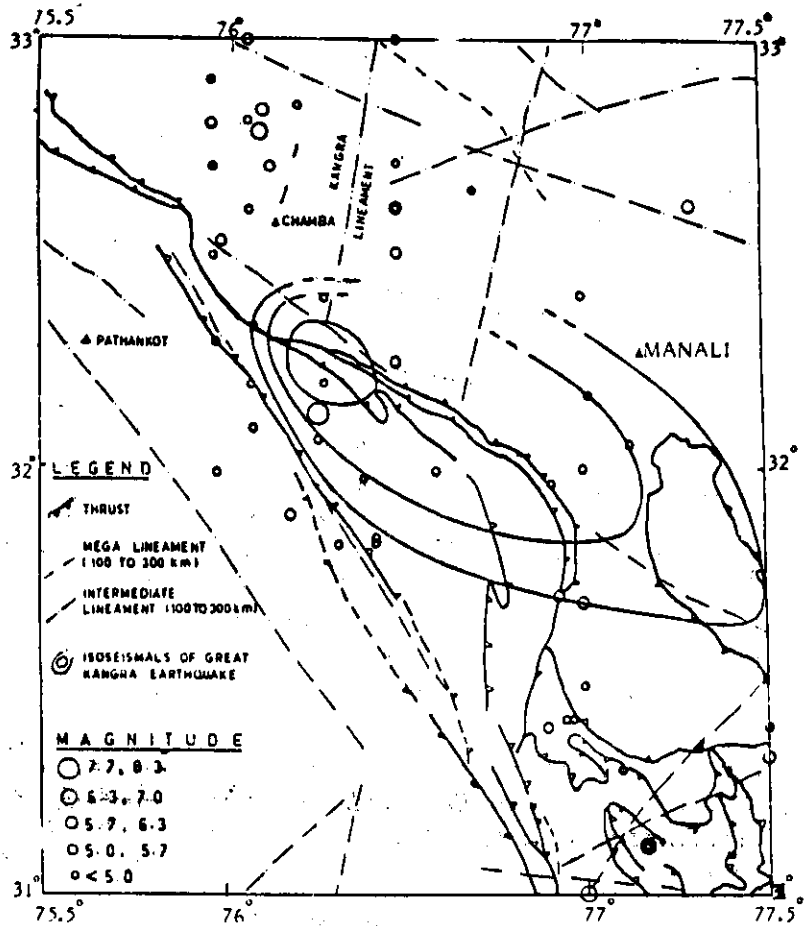

Fig. 1. Tectonic Features and seismicity in the Region of SM ARRAY in HIMACHAL PRADESH

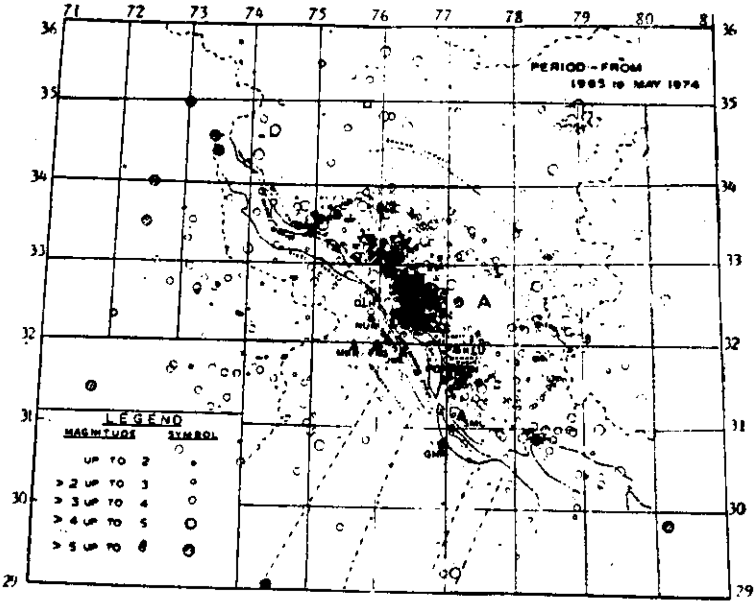

Fig. 2. ***The New microseismicity map of the western Himalayan foothills (1965-1974).—Dashed lines indicate new lineaments. (after H.N. Srivastava)***

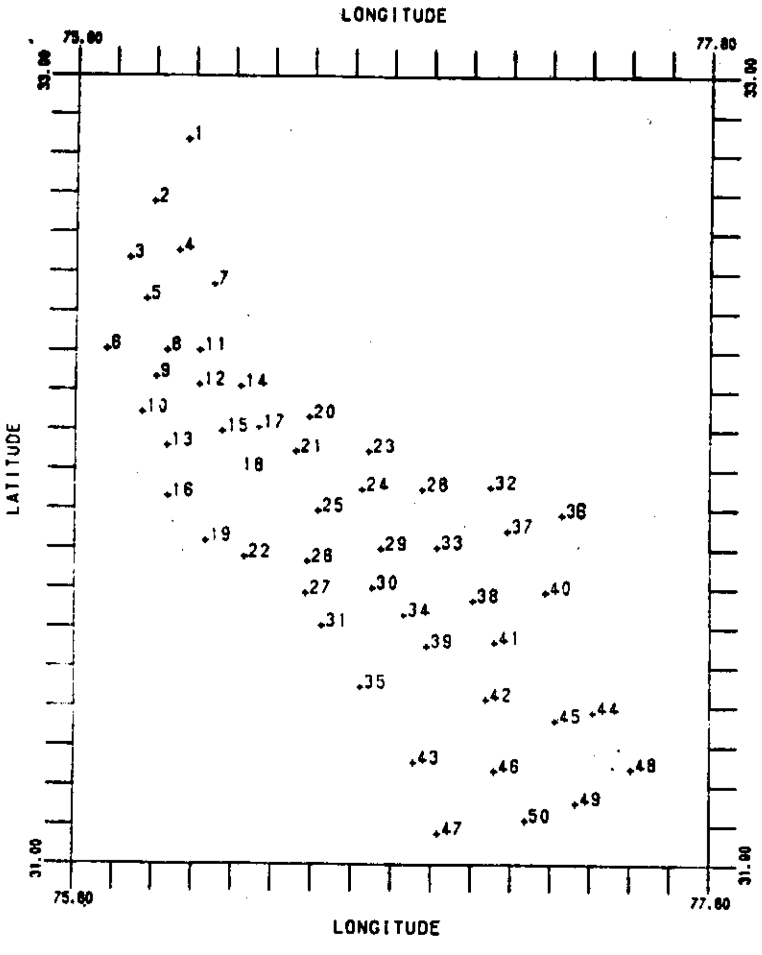

Fig. 3. Location of Stations in Kangra Strong Motion Array

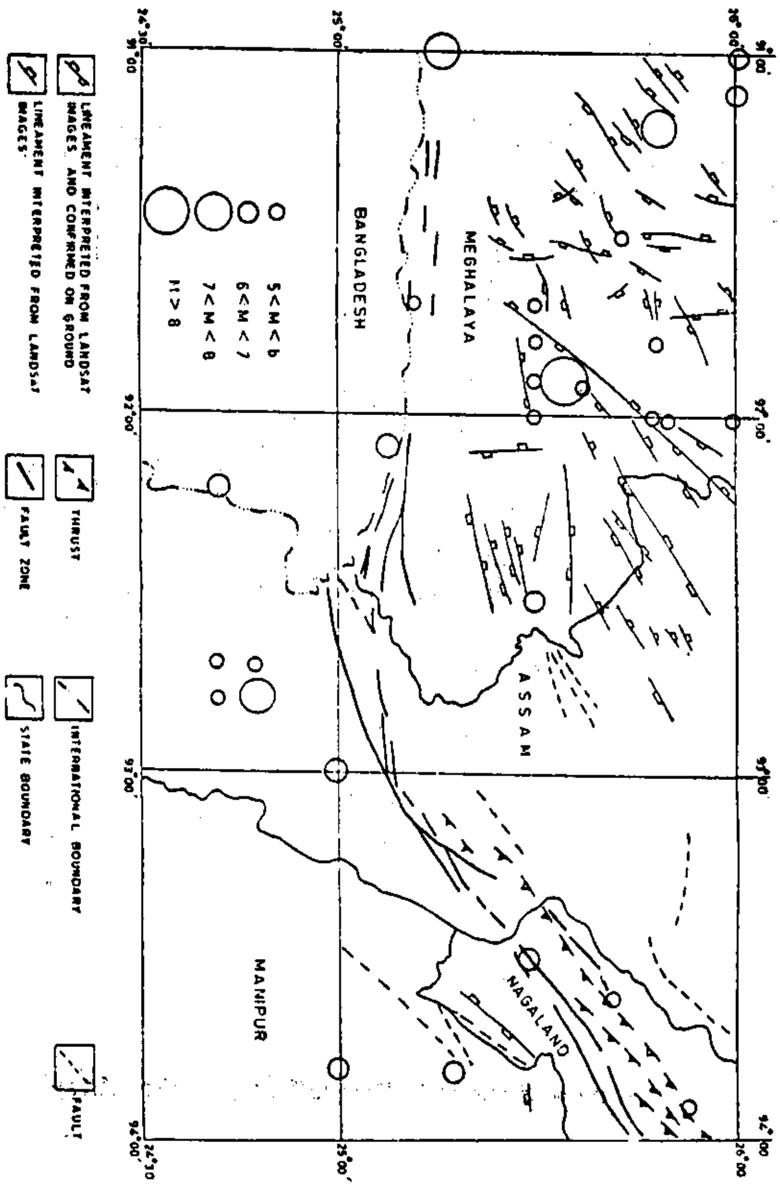

Fig. 4. Map Showing Various Tectonic Features and Epicentres of Different Magnitude in Shillong Strong Motion Array Region

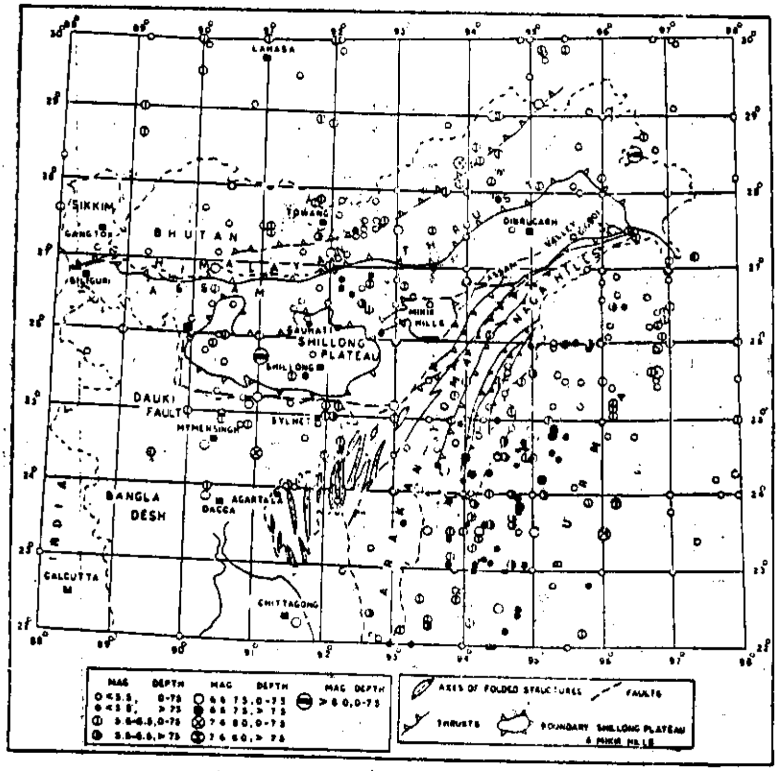

Fig. 5. Seismicity map of northeast India and adjoining areas of northern Burma and Bangla Desh for the period 1890-1970.

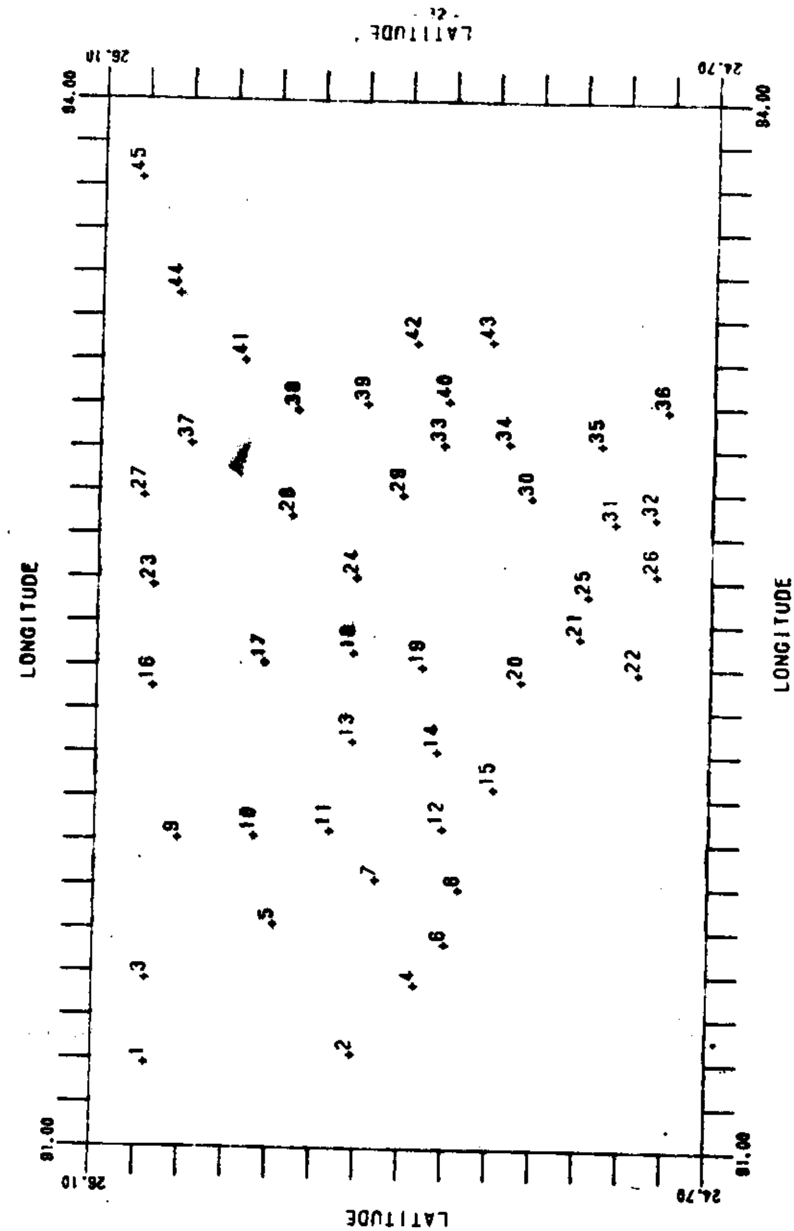

Fig. 6. Location of Stations in Shillong Strong Motion Array

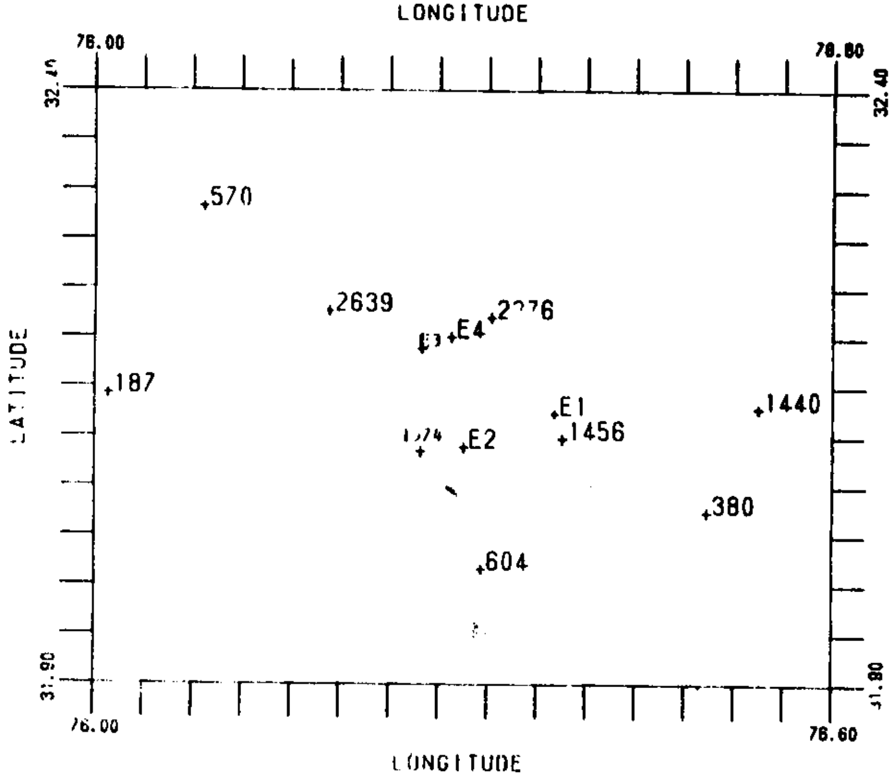

*Fig. 7. Resultant Peak Horiz. Acc. (in mm/s*s) And Epicenters-Apr. 26, 1986.*

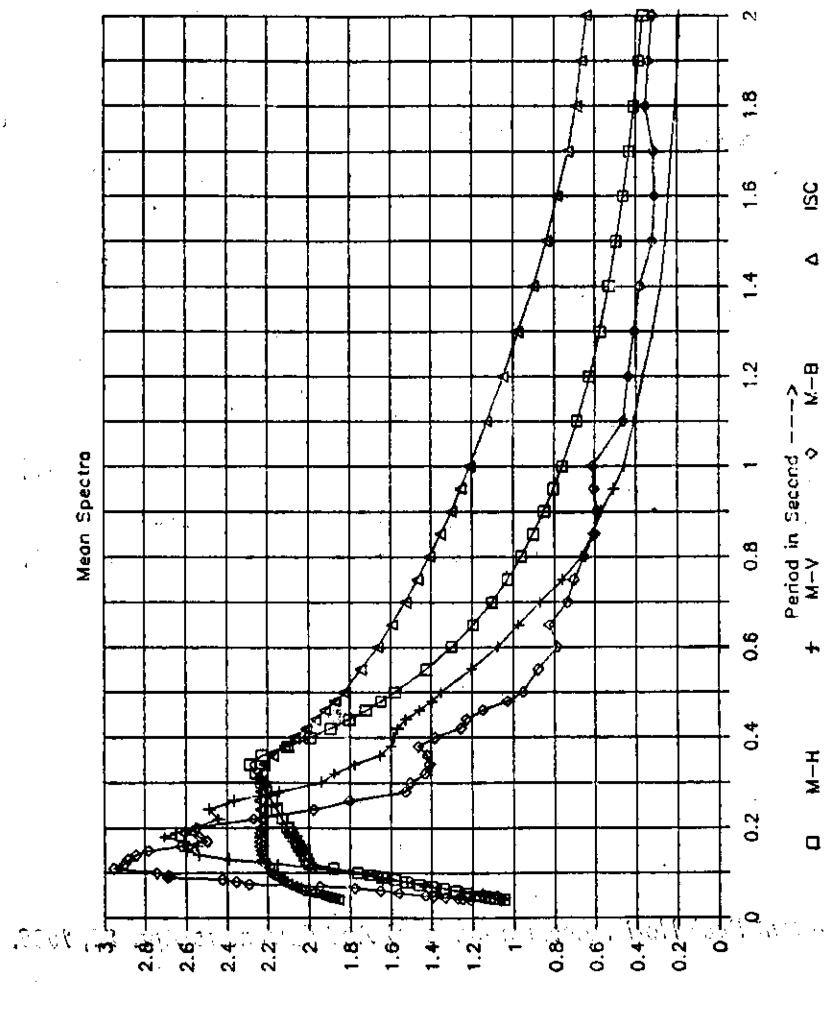

Fig. 8. Dharmsala April 26, 1986 Earthquake

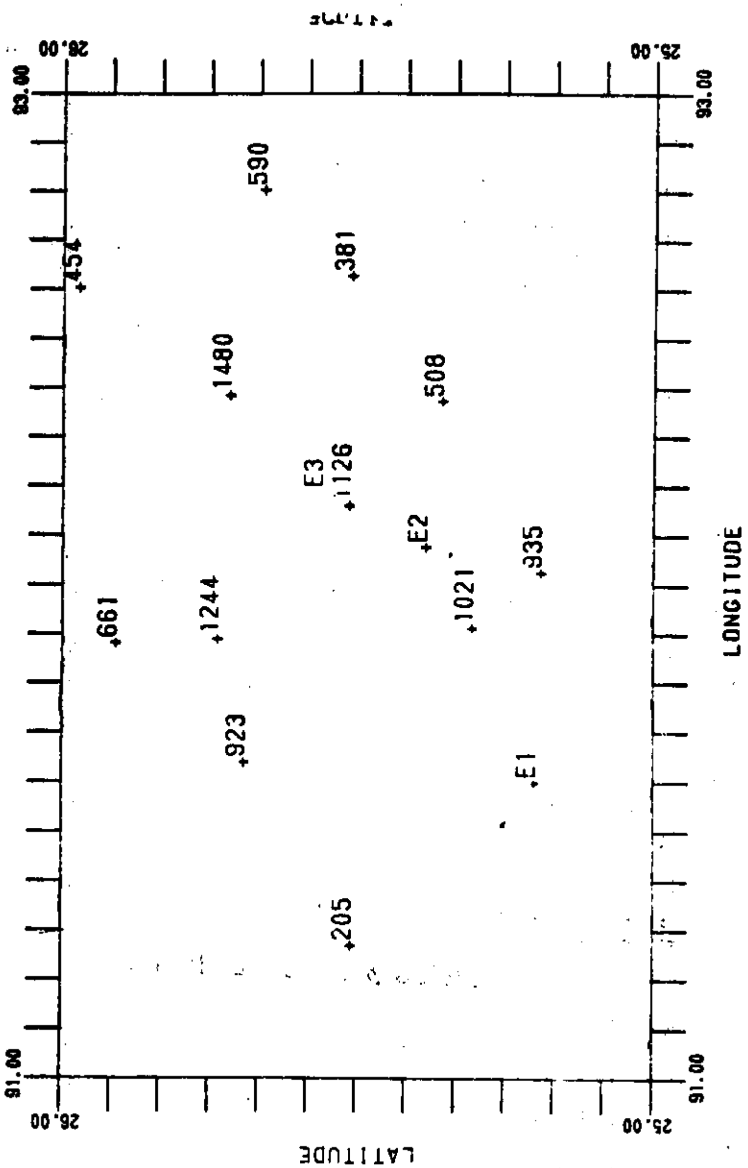

*Fig. 9. Resul Tant Peak Horiz. Acc. (in mm/s/s*s) And Epicenters Sept 10, 1986.*

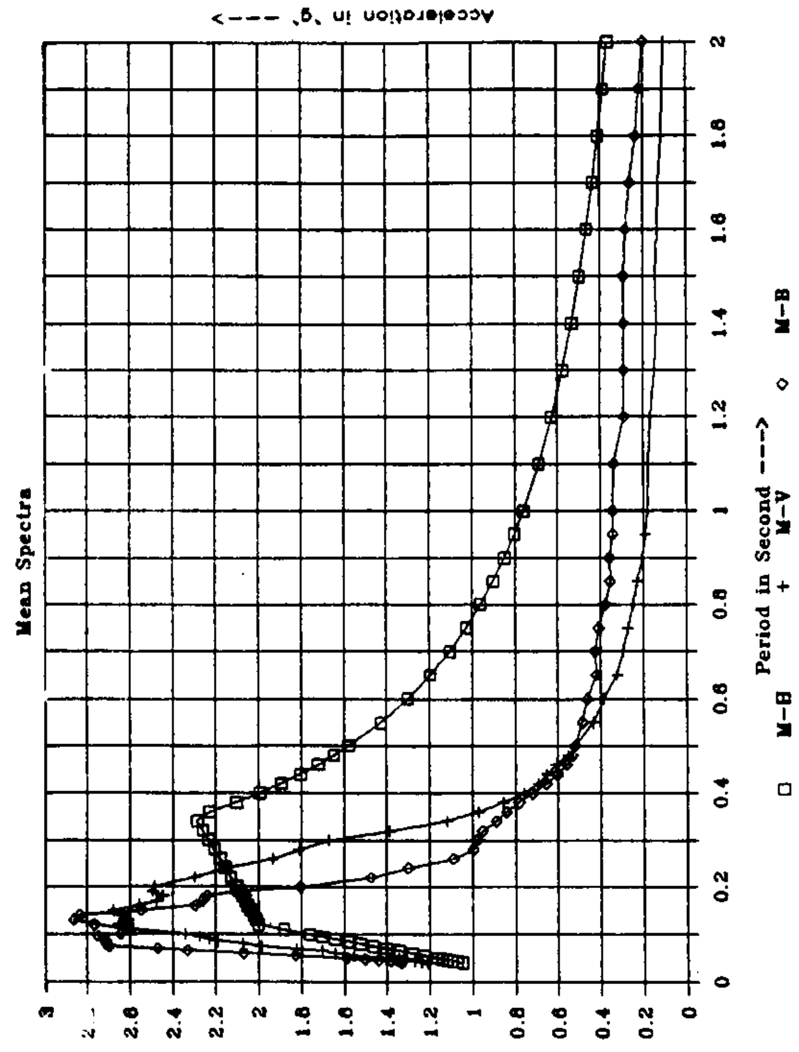

Fig. 10. NE-India Sep. 10, 1986 Earthquake

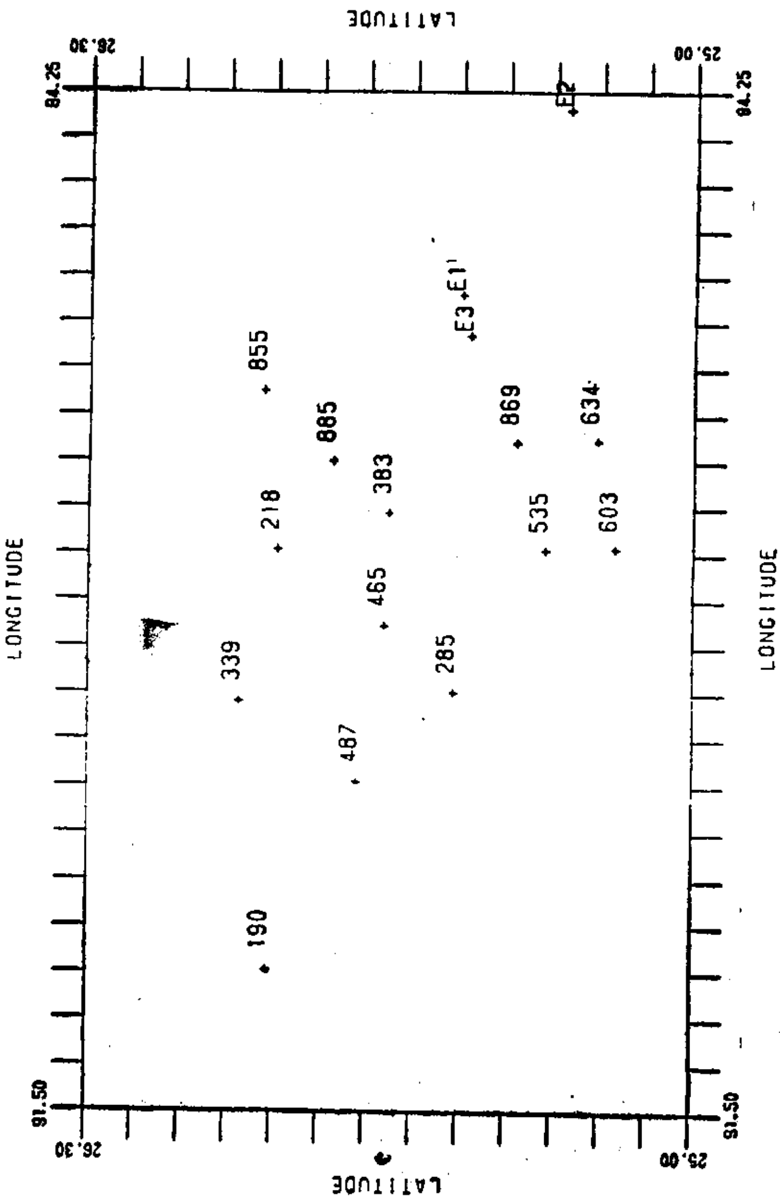

Fig. 11. Resultant Peak Horiz. Acc. (in mm/s*s) And Epicentres-May 18 1987.

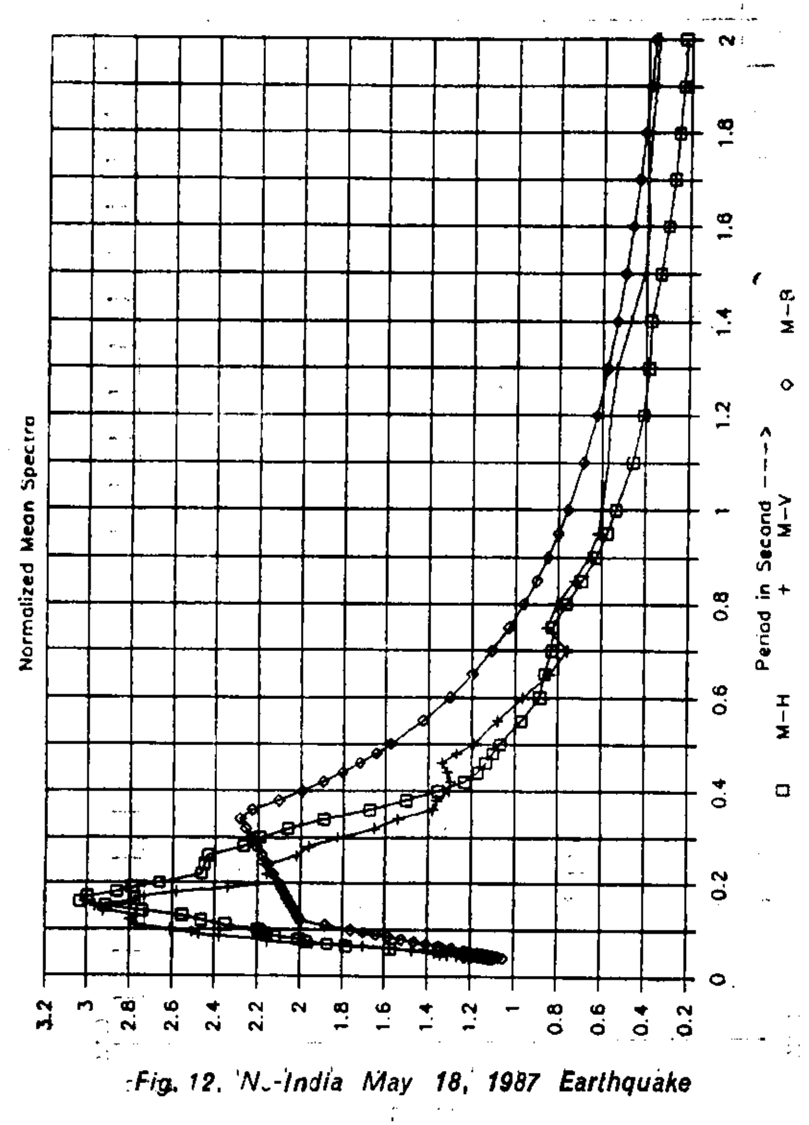

Fig. 12. 'N.-India May 18, 1987 Earthquake

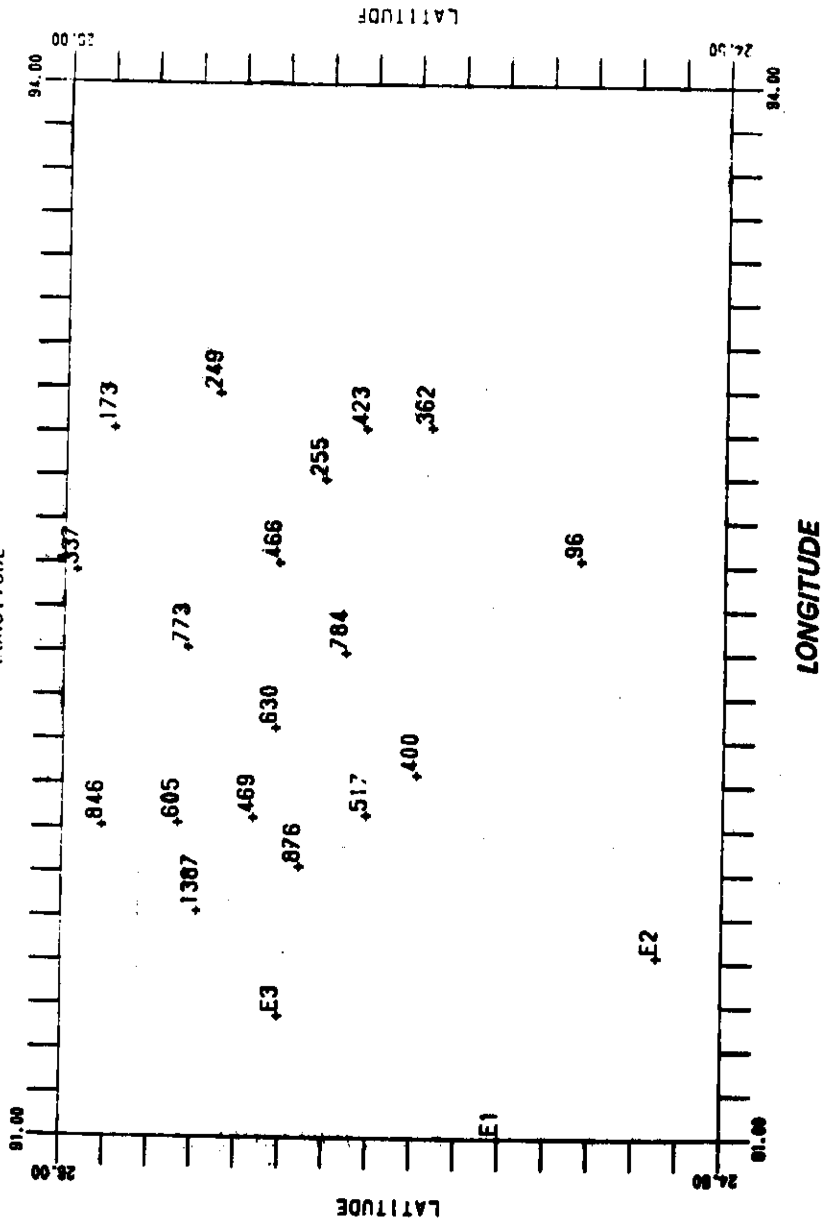

*Fig. 13 Resultant Peak Horiz. Acc. (in mm/s*s) And Epicenters-Feb. 6, 1988.*

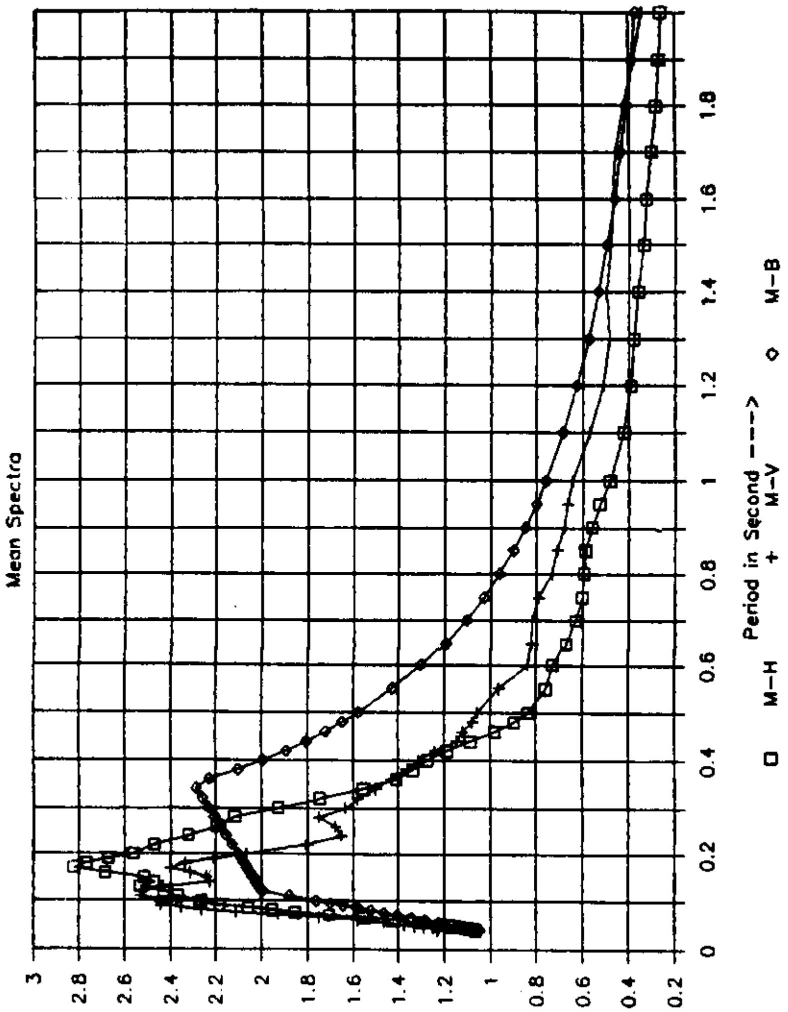

Fig. 14. NE- India Feb. 6, 1988 Earthquake

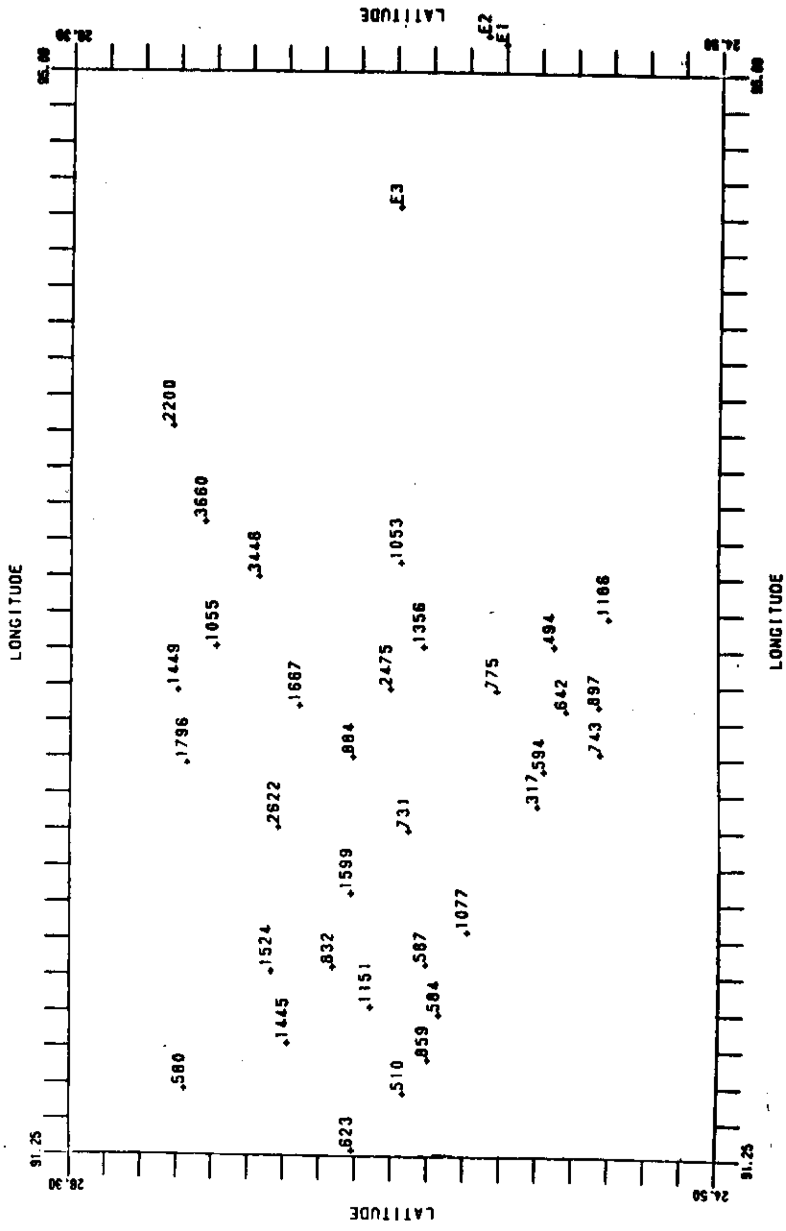

*Fig. 15. Resultant Peak Horiz. Acc. (in mm/s*s) And Epicenters-Aug. 6, 1988.*

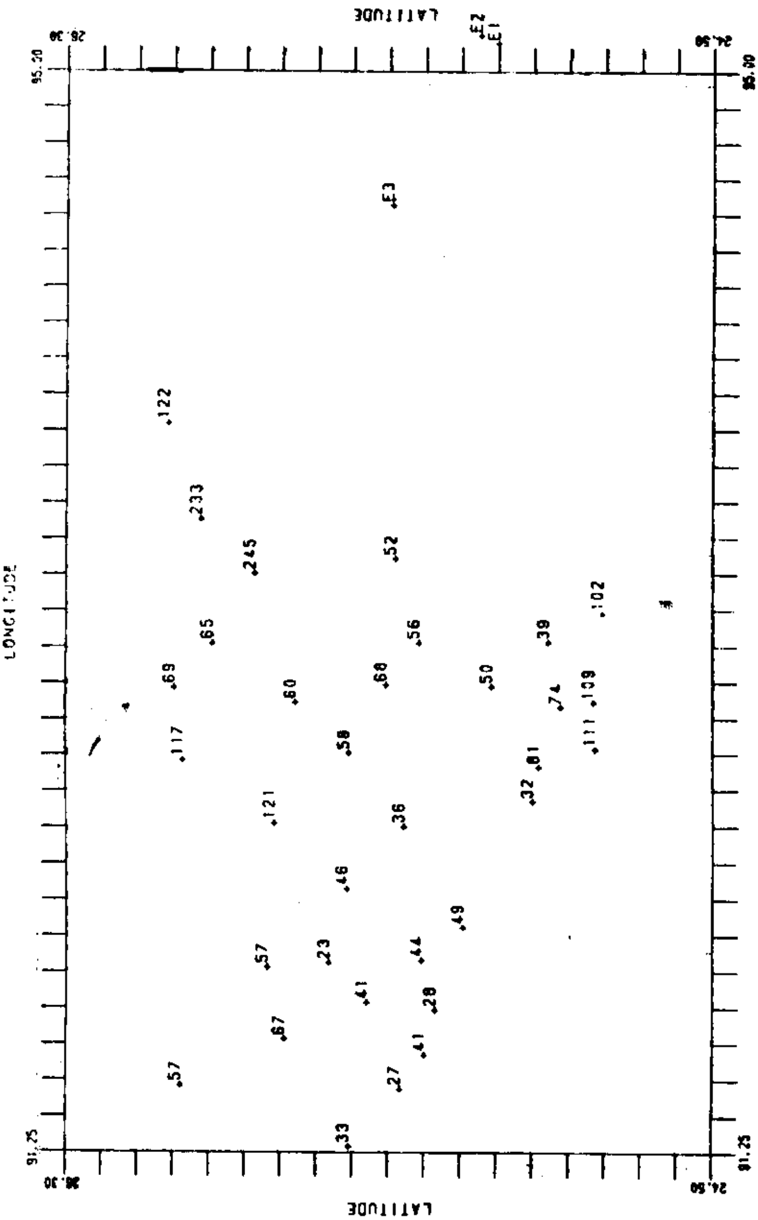

Fig. 16 Resultant Peak Horiz. Vel. (in mm/sec) And Epicenters-Aug. 6, 1988.

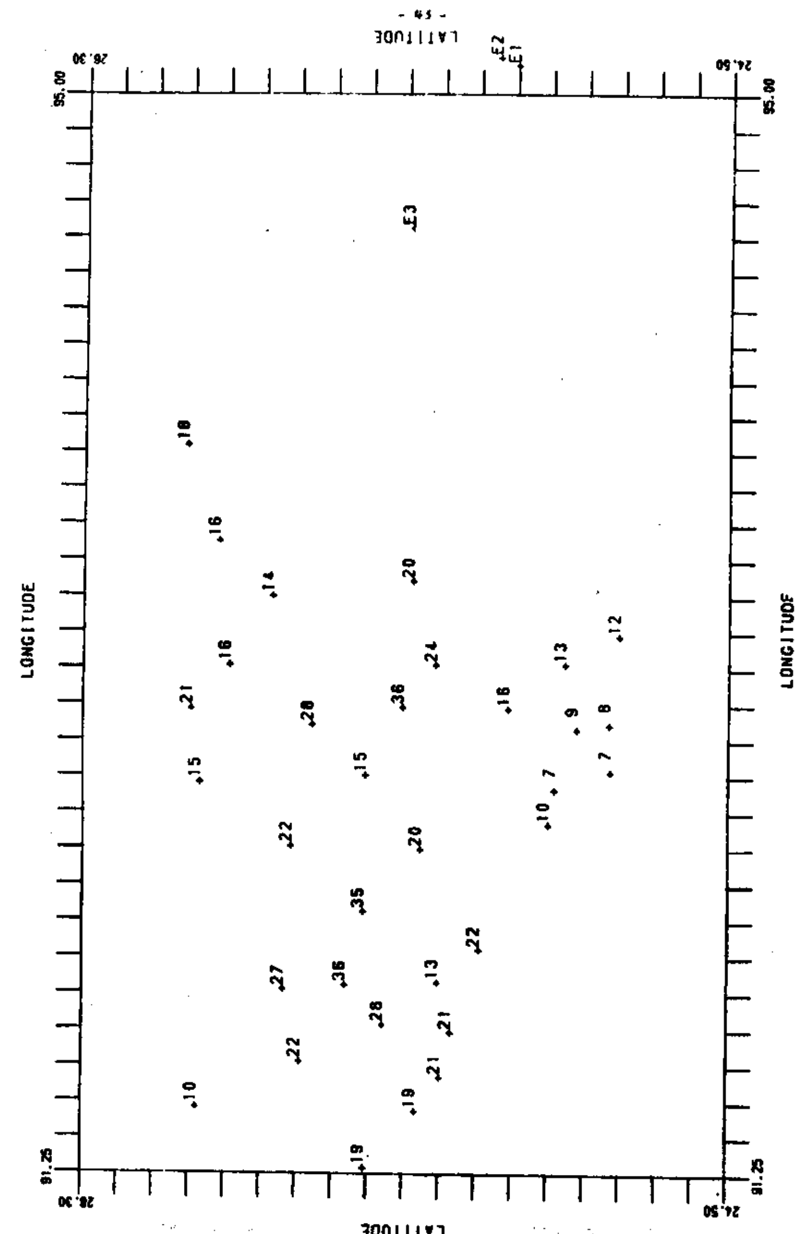

Fig. 17. Ratio of Res. Acc. to Vel. (In sec-1) And Epicenters-Aug 6, 1988

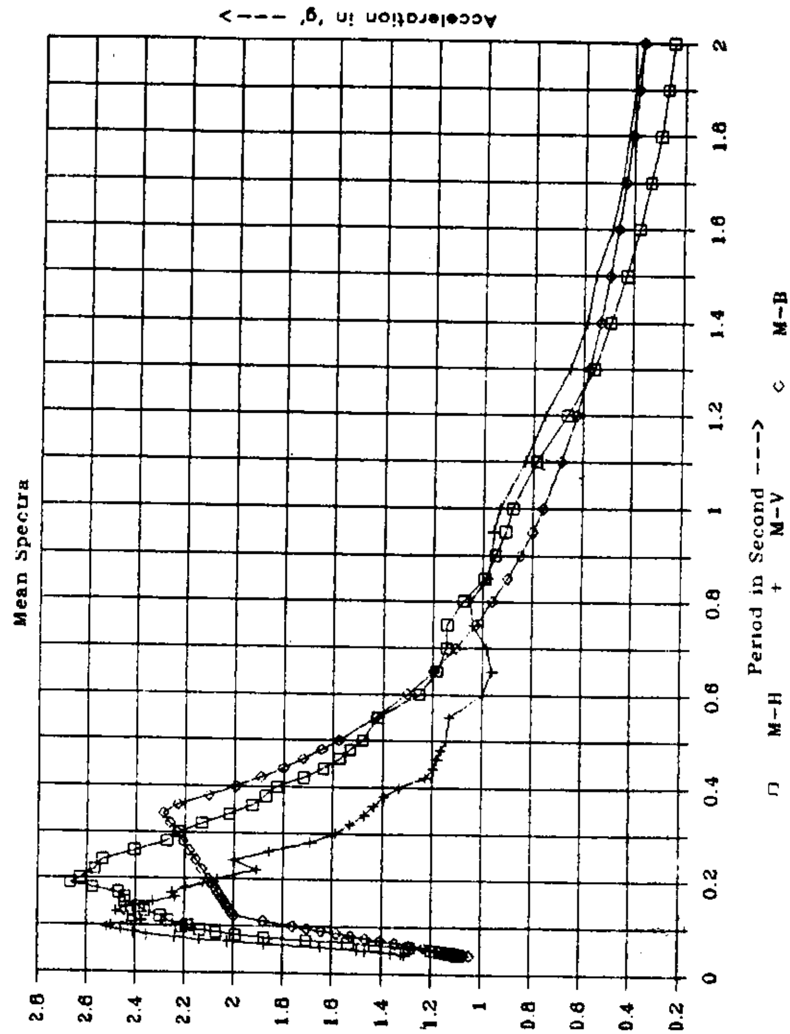

Fig. 18. NE- India Aug. 6, 1988. Earthquake

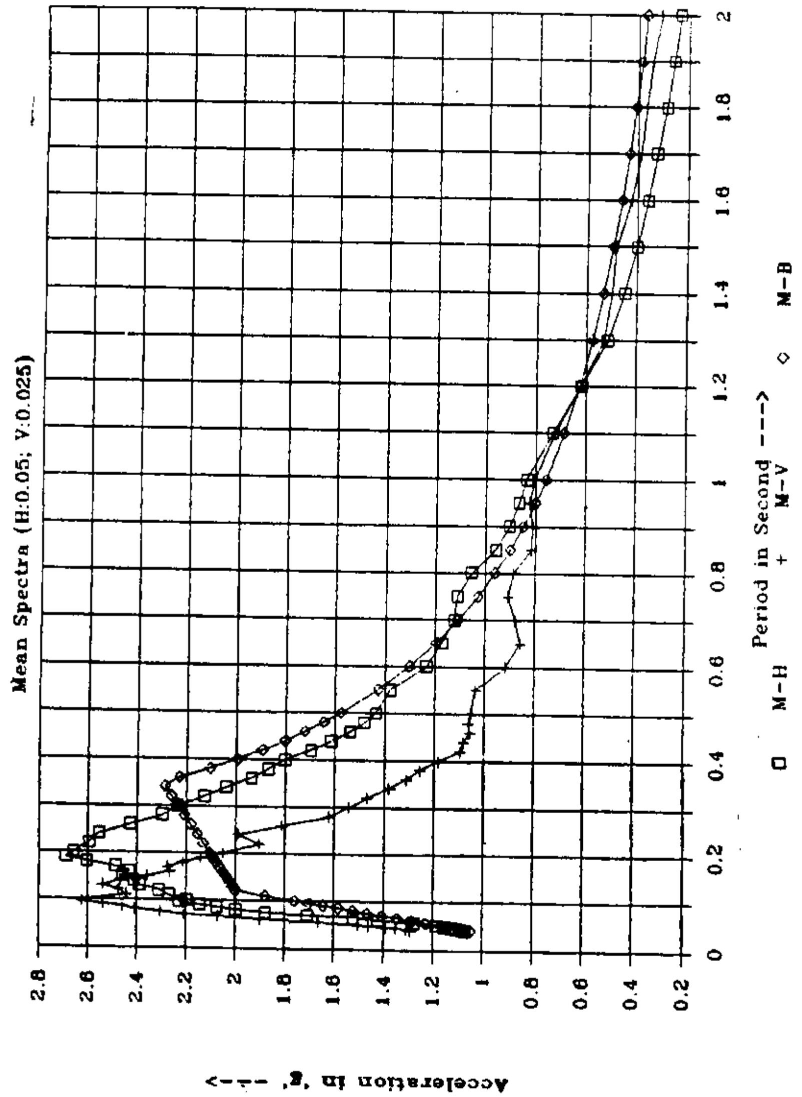

Fig. 19. NE-India Aug. 6, 1988 Earthquake

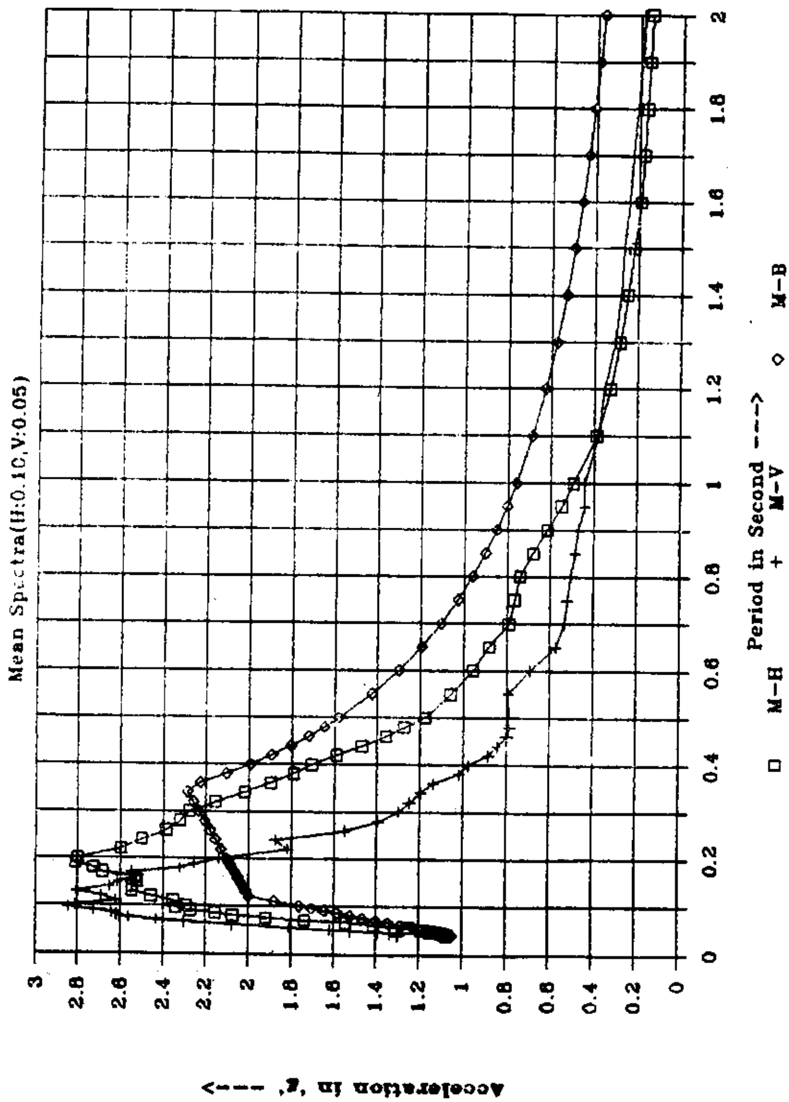

Fig. 20. NE- India Aug. 6, 1988. Earthquake

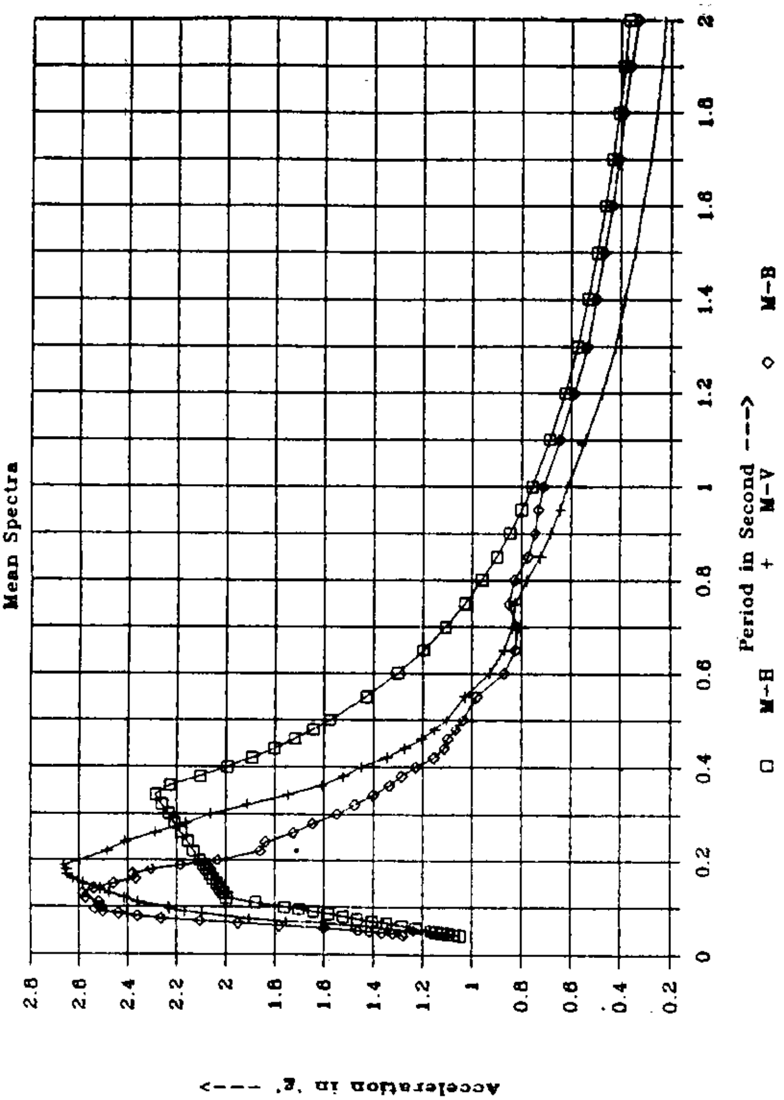

Fig. 21. NE-India Earthquakes (1986-1988)

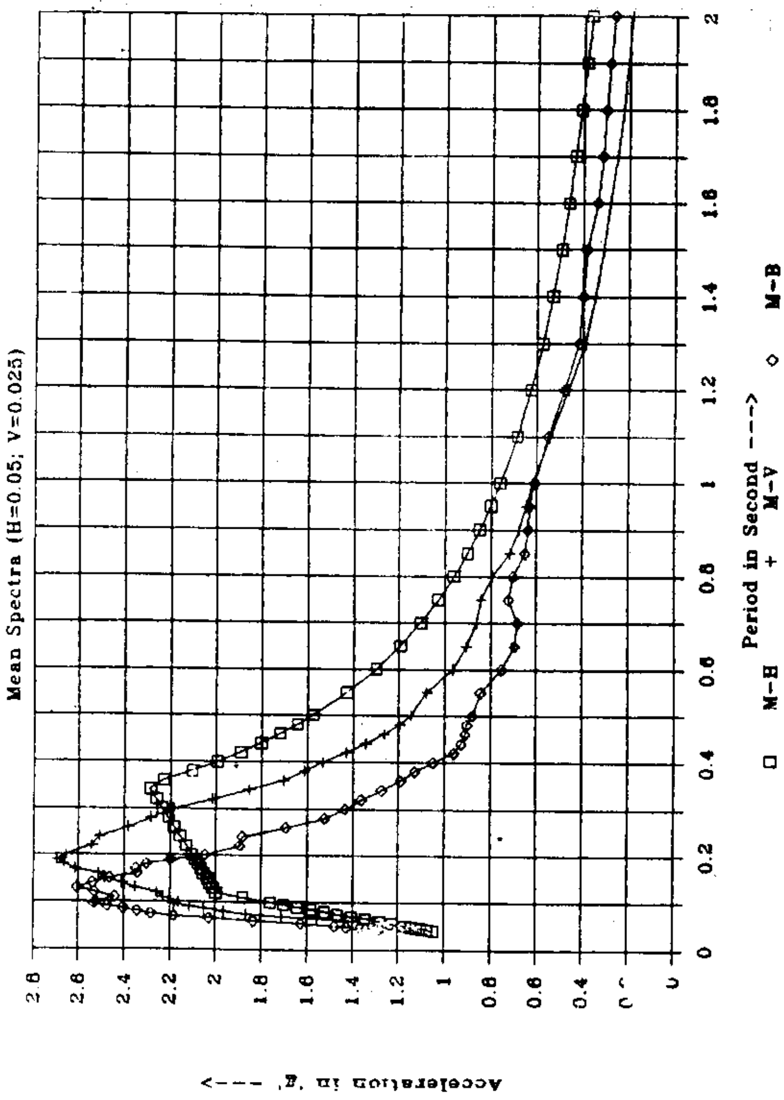

Fig. 22 NE-India Earthquakes (1986-1988)